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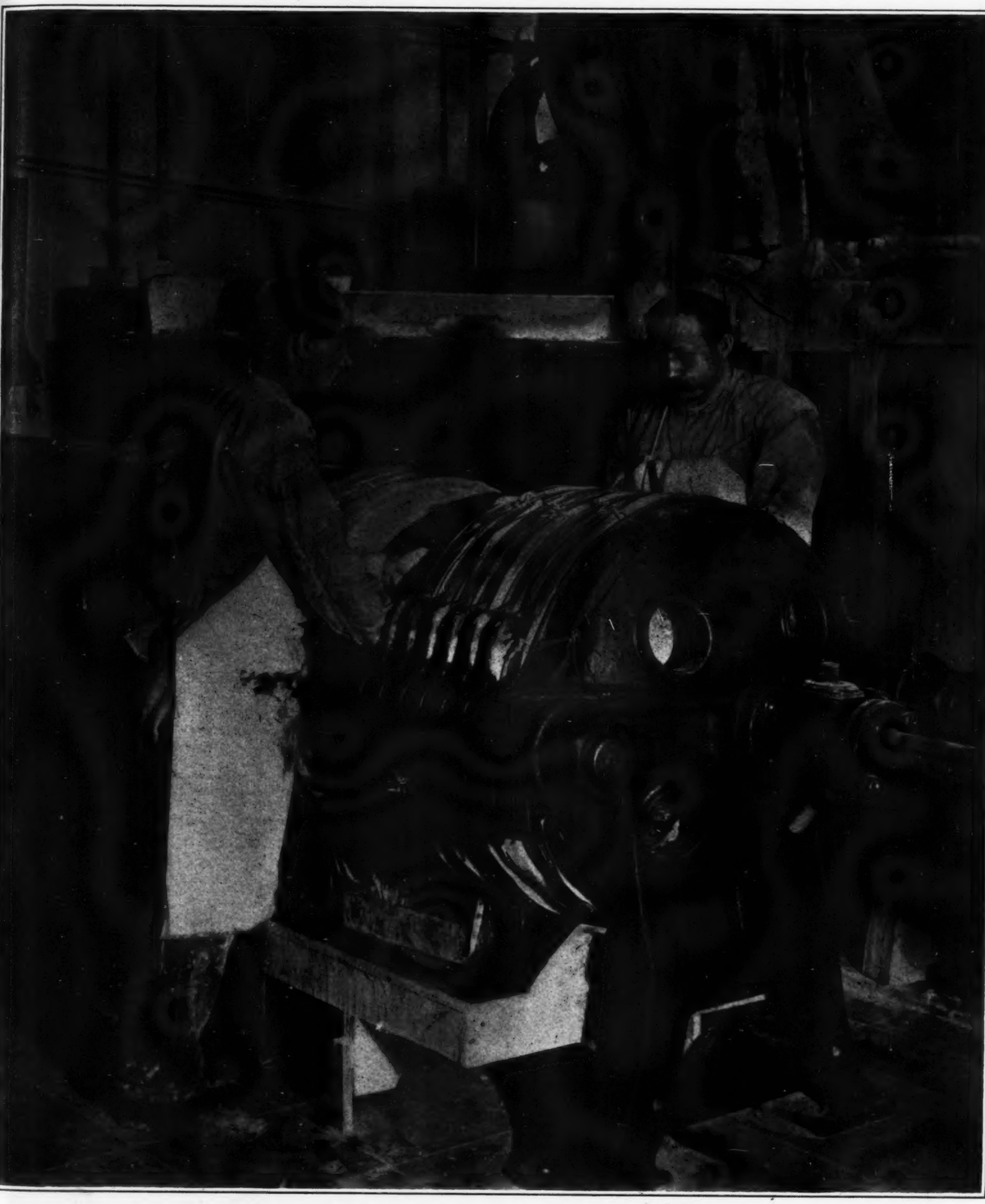


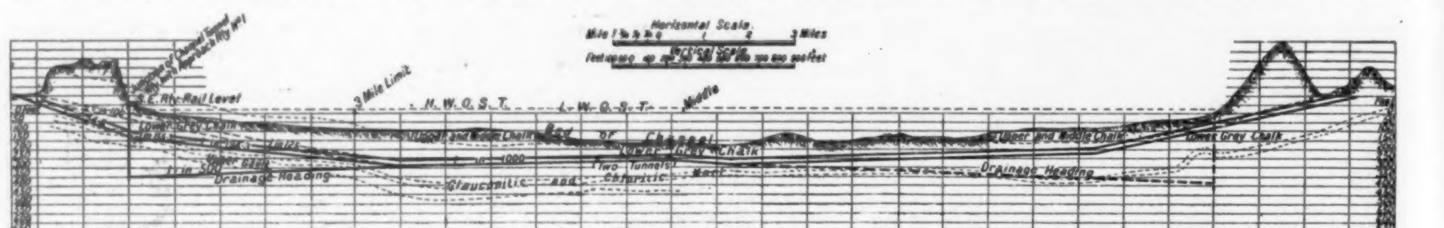
Filter press of 16,000 pounds daily capacity employed in a large porcelain works.

THE MANUFACTURE AND DECORATION OF PORCELAIN WARE.—[See page 312.]

The Channel Tunnel*

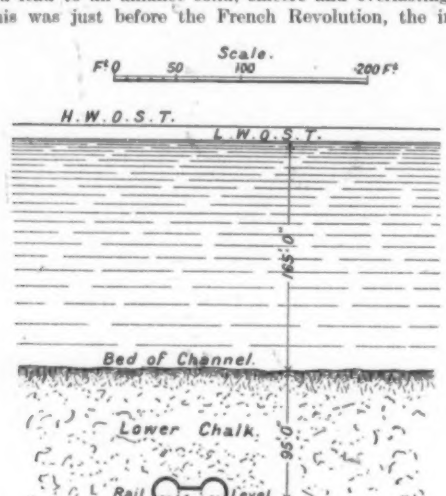
Revival of an Old Project

The great French orator and statesman, Mirabeau, wrote in a book published about one hundred and thirty years ago: "If there is a fine plan in the world it is that which would associate the greatness of France and England, founding their tremendous power upon a basis of equity." And he went on to urge the signature of a commercial treaty between the nations, which "would make national jealousies disappear forever, and lead to an alliance solid, sincere and everlasting." This was just before the French Revolution, the immediate outcome of which was an amount of international envy, hatred, malice, and all uncharitableness, unknown before, so that it took nearly a century before any realization of the far-seeing statesman's views took embodiment in the form of the serious consideration of such a scheme as an international tunnel.



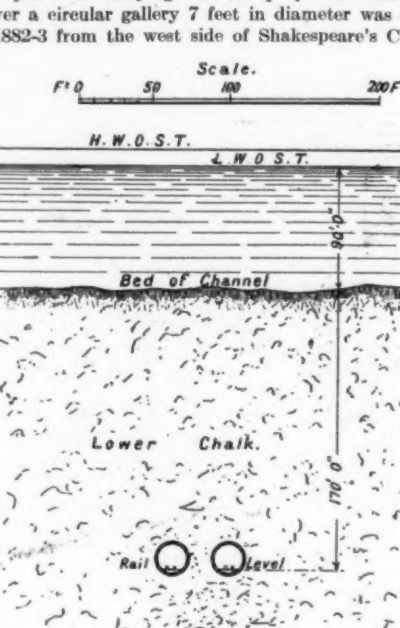
Longitudinal section of the tunnel.

Some of our older readers may remember that then, after some previous more or less efficient proposals had been made for effecting a physical junction between the railways of Great Britain and the Continent, the tunnel scheme of Messrs. Hawkshaw and Brunlees seemed to offer the best advantages, both as to practicability and cost. This was in the seventies, and in all essential points the scheme is the same, modified by modern experience, as that proposed in our day by Sir Douglas Fox and Partners on behalf of the Channel Tunnel Company, successors to the promoters, and partly identical with them, who took the matter in hand so many years ago. In fact, the engineers of the present scheme have had the advantage of the experience afforded by the trial borings and headings of the company when first formed, which were discontinued when the force of public opinion, guided by some of the military experts of the day, became hostile to the project. We do not propose, as outside our province, to refer to the objections which then led to the suspension of experimental operations on both sides of the Channel, further than to say that the recent revival of interest in the scheme does not appear to have excited its objectors to as much active opposition as was displayed forty years ago. Even then unanimity did not exist, as such prominent military and naval authorities as Col. Hozier, Admirals Colomb and Sir Erasmus Ommanney, saw no reason, from a defence point of view, why the tunnel should not be made, while in our time important supporters of the tunnel were to be found in Gen. Sir William Butler, K.C.B., Maj.-Gen. Sir Alfred Turner, K.C.B., and Vice-Adml. Sir Charles Campbell, K.C.M.G.



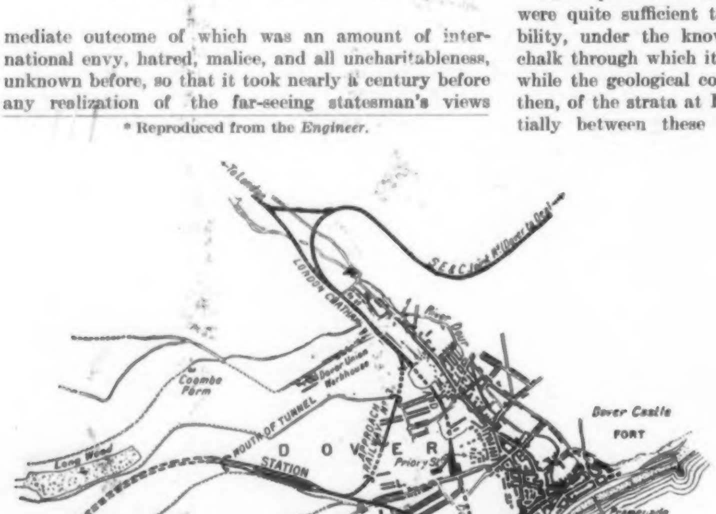
Cross section at middle point.

The experimental works, though not proceeded with, were quite sufficient to show the practical impermeability, under the known water pressure, of the gray chalk through which it is proposed to drive the tunnel, while the geological conditions, thoroughly well known then, of the strata at Dover and Sangatte, and inferentially between these points, the extremities of the tunnel, were clearly demonstrated by Prof. Boyd Dawkins, Sir Archibald Geikie, M. de Souch, Inspector-General of Mines in France, and others. These preliminary operations at Dover and Sangatte were of great importance as a practical test of what may be anticipated in carrying out the proposed works. At Dover a circular gallery 7 feet in diameter was driven in 1882-3 from the west side of Shakespeare's Cliff by Col. Beaumont's boring machine. It was completed on a descending gradient of 1 in 80 for about a mile and a third, when the works were stopped, the present

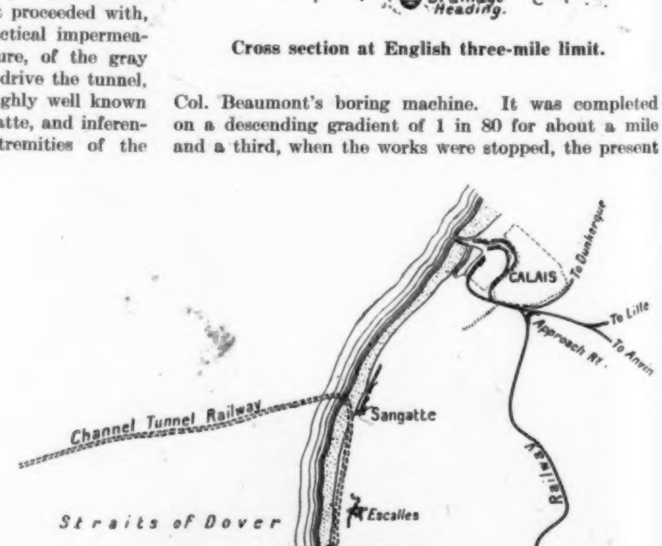


Cross section at English three-mile limit.

* Reproduced from the *Engineer*.



Approach to tunnels on the English side.



Approach to tunnels on the French side.

face being under the sea near the former end of the Admiralty pier. It is throughout in the gray chalk unlined, and proved to be practically dry, the volume of water entering the entire length being stated to have amounted to only 1½ gallons per minute, which gradually diminished. On the French side a total length of about a mile and a quarter of similar gallery was driven about the same time, also by the Beaumont boring machine, and as much as 19 yards per day represented the progress. The present face of this gallery is under the Channel about a mile from the beach, measured at right angles to the coast. The depth of the sea at this point is 27 feet below low water, and the thickness of "cover" is about 100 feet. The quantity of water entering this unlined gallery was small, and, although the water in the shaft rises and falls with the tide, the volume of water entering is not much, and the infiltration slow, as is indicated by the fact that with a rise and fall of tide of 18 feet the water in the shaft rises and falls only to the extent of a few inches.

The strata which form the coast of England, between Dover and Folkestone, and of France, between Sangatte and Wissant, and which lie beneath the English Channel between these points, dip in a northerly direction. In 1876-7 the French geologists, Messrs. Potier and Lapparant, took some 7,600 samples of the bottom of the tunnel, 3,267 samples of which they were able to utilize. It was found from these that the lines of outcrop from the strata are very nearly parallel to a line drawn from Folkestone to Sangatte. It is this information which has guided the provisional alignment and section of the proposed work. It is true that a possibility exists of the occurrence of fissures through the impermeable chalk, destroying its continuity, but the engineers argue that such fissures would have been long since filled in with a deposit, which under its own pressure and that of the sea above it would be scarcely less dense and impermeable than the chalk itself.

The engineers of the English half of the work, Sir Douglas Fox and Partners, have considerable experience in tunnels, including much subaqueous and other work, involving contention with water pressure, notably the Mersey Tunnel and a large number of others in all parts of the world, aggregating about 50 miles. They are, therefore, armed with the valuable weapon of experience, in dealing with the most economical and efficient methods of carrying out an undertaking, which, though on an unprecedented scale, offers, it is argued, no difficulty which has not been surmounted by them and other engineers in many parts of the world.

In giving a few particulars of the proposed works, it should be premised that until the authority of Parliament, which is expected to be asked for next session, is obtained, they are liable to be modified after the closer investigation which will then be necessary. The French company, which will deal with the continental half of the scheme, has already legal powers to begin.

The Hawkshaw-Brunlees tunnel was to be of 30 feet internal diameter for a double line of rails, and, of course, was intended to be worked by steam operation, and even under that disadvantage, as compared with the electrical working now proposed, the ventilation was not looked upon as an insuperable difficulty. The air was to be dealt with by means of 230 horse-power engines at each end, and it was calculated that with half-hour trains it would be possible to keep the air freer from noxious gases than the steam-worked Metropolitan Railway, and of many of the gas-lighted theatres of that time. The figures given as regards carbonic acid gas were, in fact, as follows: In the tunnel it was expected that 3.50 parts in 10,000 would be the minimum, and 16.25 would be the maximum, with a mean of 9.84, whereas in the steam-worked Metropolitan Railway there was a maximum of 22.5, and in the London theatres 20.0 to 30.0.

It is proposed in the present project not only to install electrical working, giving rise to no deterioration of the air, but to construct a separate tunnel for each line, as in the London tubes, so that the direction of the traffic in each would be constant, which tends, experience has shown, to aid such ventilation as may be provided by fans. At frequent intervals along the entire distance cross-passages will be constructed and fitted with air-tight doors. These galleries will be placed obliquely in order to facilitate the passage of trains of material, both from and to the advanced faces, and for the primary ventilation. Thus, the construction trains, as also the main air current, will enter by one of the main tunnels, and, crossing over by the most advanced oblique passage, return by the other tunnel. The secondary ventilation will commence at the last oblique passage. Upon the completion of the work these galleries will serve as a means of communication between the tunnels for the workmen on the railway. The traffic being electrically operated, the volume of air required, as compared with steam working, will be much reduced. It is assumed as a maximum that there will be a passenger train each way every ten minutes, carrying 500 people. The volume of air per minute required to keep the tunnels fresh will be about 45,000 cubic feet each way, traveling at a velocity of about 6 feet per second, which is equivalent to a very light breeze. There will be no difficulty in providing this, it being far less in proportion than has had to be provided elsewhere. The power required to induce this current of air, much assisted as it will be by the trains, will not be large. Hence, whatever doubt may have been entertained as to the soundness of the opinion of the promoters of the Channel Tunnel forty years ago as to ventilation troubles, this particular objection has practically disappeared from the list of those put forward by the opponents of the work.

The Channel Tunnel will comprise, as shown in the accompanying sections, two distinct sets of bores, one of which, the drainage heading, will start from the bottom of a shaft at Dover at 350 feet below sea level, and will rise on a grade of 1 in 500 to about six miles from the shore, where it will meet in a vertical plane the main railway tubes, descending on easy gradients to this point, and proceed on one side of the tubes on a still rising grade of 1 in 1,000 to the summit at mid-channel, meeting the French work, which will follow the same plan. It is probable, but not certain, that the drainage heading, 24 miles in length, will be put through before the main tubes will be started. This drainage heading will be driven by a shield and connected with the tunnels at such points as may be found desirable, not only for drainage purposes and for the removal of the excavated materials, but also as supplementary to the main system of ventilation. This drainage heading will probably have to be lined with cast iron. The plates would be machine-faced and of sufficient strength to resist the full pressure, and, being grouted up, would be water-tight. The only possible water-yielding area would be thus the actual face exposed, and one length of chalk to be covered by the next ring of cast iron. The excavation would be effected by some approved cutter or by Price's electrical digger, used in the tube railways of London. An advance of 5 feet per hour can be secured both in excavation and also in the fixing of the iron lining, but, allowing for inevitable delays and for the long distances from the shaft, a speed of 2¼ feet per hour can be relied upon for six days in the week. As Sir Francis Fox pointed out in a paper read before the recent Congress of the Franco-British Travel Union, assuming that a rate of progress of 17 yards per day can be maintained for six days per week, this would represent an annual advance of about three miles at each face, occupying a period of four years to drive the drainage heading from the English to the French shaft, 24 miles. Three shifts of men would have to be employed, and the changing should take place below and on the spot, no stoppage of work being allowed. This was the system in the case of the Simplon Tunnel, where the drills never stopped, even while the shifts were changing. An emergency door would always be kept in position near the face of the heading, not so much for actual use, but rather to induce confidence in the minds of the men at work. In order to allow two sets of wagons passing one another and at the same time to leave sufficient space for air, water, and power pipes, cables, etc., the diameter of the drainage heading cannot be less than 11 feet internal diameter. In view of the possibility of water-bearing fissures being met with, a pilot drill will be attached to the boring machine, so that there will be ample warning of the necessity for special precautions, such as liquid grouting under pressure. As much as 500 pounds per square inch has been used successfully in similar cases.

The main tunnels will consist of two single-track tubes each of 18 feet internal diameter, and thus large enough to accommodate the rolling stock of the British and French main lines, except only their engines, for which would be substituted electrical locomotives of ample power to deal with the heaviest trains running on the main lines. The advantages claimed for this plan as compared with the construction of a double two-track tunnel are that the vertical dimensions are much reduced thereby, rendering it easier to adjust the position of the tunnels, so as to be entirely within the gray chalk stratum, the better ventilation of the works both during construction and after completion, the reduction in the cost of lining and the more easy application of the system of shield, combined with the mechanical excavator. The total length of these twin tubes and the approaches to connect with the main lines of the two countries will be about 31 miles. The tubes will be placed 32 feet apart from center to center, and they will be lined throughout with cast iron segments of ample strength to resist any possible pressure, and grouted on the outside in the usual manner by means of the "Greathed" grouting machine. By this method the exterior of the tunnels will be completely surrounded by a covering of cement, which not only prevents leakage into the tunnel, but will also preserve the plates from corrosion. When the plates are in position the inner face will be lined with concrete and cement and lime-washed, thus providing a smooth interior surface, so that in the case of the derailment of a train, little damage would accrue, owing to there being no projection or obstruction. This lining will preserve the plates from corrosion on the inside, and will also materially assist the ventilation. In certain places, where the necessity of the work of construction or of the traffic demand it, an enlarged cross-section of tunnel will be provided, where the hauling machinery for removing the spoil can be placed, and pumps and ejectors for freeing the tunnel from water fixed. These will also serve as block stations for the signalling equipment. The completion of the whole work is expected to take seven years. So much for the sub-marine section.

As to alignment of the approaches landward, on the English side the coast line will be crossed by the tunnel close to the southwest face of the present Shakespeare Cliff tunnel on the South-Eastern Railway under that line, and proceeding, spiral fashion, still in tunnel, around the citadel and the villages of Farthingloe and Maxton, will reach the surface close to the northwest of the latter. East of the face there will be a new station, and just beyond, a junction leading into the London, Chatham and Dover Railway, connecting via Canterbury and Chatham with Holborn Viaduct and Victoria. Proceeding from this junction to complete the spiral, the approach will end by a junction with the main line of the South-Eastern Railway in the London direction close to the Shakespeare Cliff tunnel eastern face, and forming direct connection through Folkestone with Charing Cross, London Bridge, and Cannon Street stations.

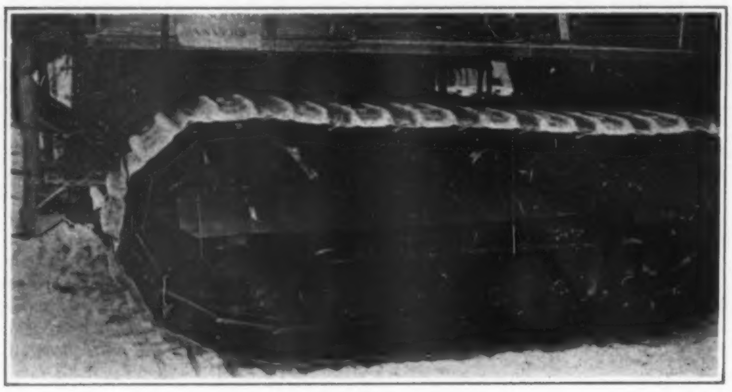
Plan of the tunnels and approaches.

On the French side the alignment will cut the coast at Sangatte, and turning sharp to the right will proceed parallel with the shore, the rails reaching the surface near Wissant on the coast. The approach will there form a back shunt junction, joining the Calais-Boulogne section of the Chemin du Fer du Nord at Beuvréquent near Marquise. This is clearly shown in the accompanying plans.

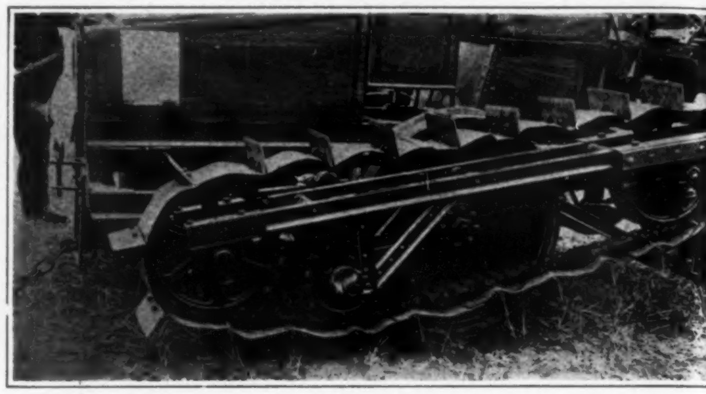
It will be noted that in order to keep within the gray chalk limits there is a curved alignment in the subaqueous portion of the tunnel, requiring very special care in the setting out, so that the headings may meet in mid-channel fairly accurately, but there is not much danger of these missing each other, either vertically or horizontally, when we consider the achievement in this respect of such long alignments as that of the great tunnels of the Alps, and those of the Severn and Mersey.

As to the approach land tunnels, these will be constructed in brick according to the usual practice for such work. The estimated cost of the British half of the undertaking, including the purchase of land and buildings, and the existing works at Dover, the electrical installation, the drainage heading and its shafts, winding and pumping machinery, the land approaches, the sorting station and sidings, and the junction with the South-Eastern and Chatham lines, the main tubes, with administration, parliamentary expenses, legal and engineering charges, interest during construction, and financial expenses, with the necessary provision for contingencies, is $40,000,000, and it may be considered that the French half of the work will cost approximately the same amount, making a total of about $80,000,000 for the entire project.

The diagrams herewith are reproduced from Sir Douglas Fox's report of 1907.



The traveling track of the "Caterpillar" tractor.



Lefebvre tractor. A bladed belt furnished the requisite adherence with the ground.

Tractors for Farm Service

Types Exhibited at the Soissons Contest

In Europe the need for mechanical aids to agriculture has not been felt quite as keenly as in this country, partly owing to the comparative cheapness of labor, and partly owing to the smaller scale on which operations are carried on. But at the present time a very lively interest is being displayed in machines adapted to European conditions, and this interest found expression at a recent exhibition and contest held at Soissons, in the Department of Aisne, France.

Among the exhibits there shown and tested, one which attracted particular attention was the "Caterpillar," an American machine, which was making its debut upon the French scene at the Soissons contest. This machine measures nearly 20 feet in length and 11 feet in breadth. Its weight is about 10 tons. The mechanism by which propulsion is effected, and to which the machine owes its name, is perhaps the item of chief interest about it.

The chassis rests upon two sprocket chains, which form a traveling track laid around two pairs of sprocket wheels. Each chain or traveling track is composed of steel plates linked together at the points and carrying on the inside two straight bars that form a section of the rail or track. A series of small running wheels resting upon the movable track support the weight of the machine. Thus the effective base upon which the machine rests measures over six feet in length by 18 inches in width on each side. This gives a load of not over 6½ pounds per square inch.

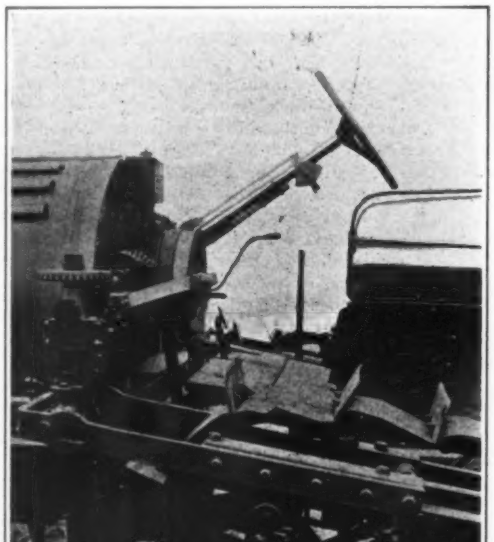
At the front end the chassis rests upon a corrugated steering wheel. If it does not carry much weight, its guiding action would not always be very effective, and in point of fact reliance is not placed upon it alone, but the two "caterpillars" are actuated separately and can thus be used to negotiate curves and turns.

The motor is a four-cylinder, sixty-five horse-power automobile motor with magneto ignition. The cooler is a vertical pipe water radiator. The transmission is a horizontal shaft with friction clutch carrying a bevel gear which actuates two fly wheels with internal expansion clutch. Each of these clutches has separate control, and it is by means of them that the right or the left caterpillar or both are put into action.

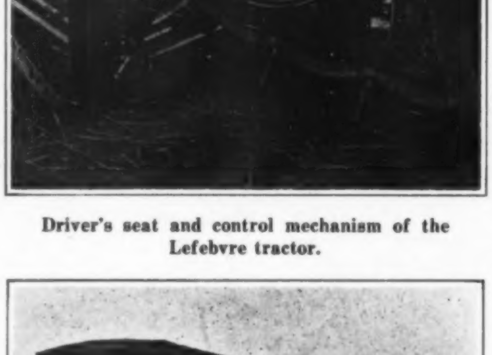
There is only one speed, though of course the motion can be reversed. Power for purposes other than locomotion of the machine can be taken from a pulley at the core.

A plough with ten ploughshares is furnished with the tractor. The ploughshares are controlled through levers by an attendant stationed on a platform on the machine. Two men are thus required to handle the machine, one to act as driver for the tractor, the other to take care of the ploughs.

Another interesting type of tractor exhibited is the Lefebvre. Outwardly this resembles in some points the Caterpillar, having like the latter, endless bands for providing the requisite contact with the ground over which it travels. Here, however, the weight of the machine is not supported upon this endless band, but upon ordinary wheels. To give a good grip on the soil the endless belts referred to above carry transverse strips or plates whose action will be obvious from the accompanying illustration.



Driver's seat and control mechanism of the Lefebvre tractor.



The "Caterpillar" harnessed to a plough.

The Chemical Effect of Polarized Light

By E. G. Bryant

In many parts of the world, more especially in tropical regions, there is a widespread belief in the deleterious effects of moonlight on fish, and to a lesser degree on meat intended for food. This belief is by no means confined to sailors, fishermen, and other superstitious or ignorant persons. Many doctors are convinced of its truth—it has been officially given as the cause of death in at least one South African inquest; I have received some most trustworthy statements of the ill-effects produced in persons who had partaken of fish that had been so exposed. There are also closely allied beliefs as to the danger of sleeping with the tropical moon shining full on the face, the effects of moonlight on seeds, on growing plants, and the rising of the sap in wood.

It seemed to me that a possible explanation of these phenomena, supposing them to be true, might lie in the well-known fact that the light of the moon, being reflected light, is more or less polarized. I examined all the authorities at hand, but could find no reference to any work carried out on polarized light with reference to its chemical effects.

I therefore made an endeavor to test for any such effects, and this short note embodies the results I have been able to obtain. For one or two experiments I had the use of a 200 candle-power Osram lamp, but the others received only light from a 32 candle-power carbon-filament lamp. The light was polarized by means of a pile of seven sheets of plate-glass, backed with a silver mirror and placed at the correct angle. I hope to be able to continue the work with the larger lamp, as it is evident that no decisive results can be obtained without a fairly powerful beam of light.

The most marked results were obtained from fish. If two slices, cut from the same fish, were hung, one in the direct light, the other in the polarized beam, the latter invariably began to decompose before the former, though the temperature of the polarized beam was several degrees lower than the direct light. These experiments were carried out with the large lamp. Tests were arranged with the small lamp on meat, jam, cane-sugar solution and several kinds of seeds. The sugar showed absolutely no change; of the others, none could be called decisive, but whenever any difference was observable it was always in favor of the polarized light.—*Chemical News.*

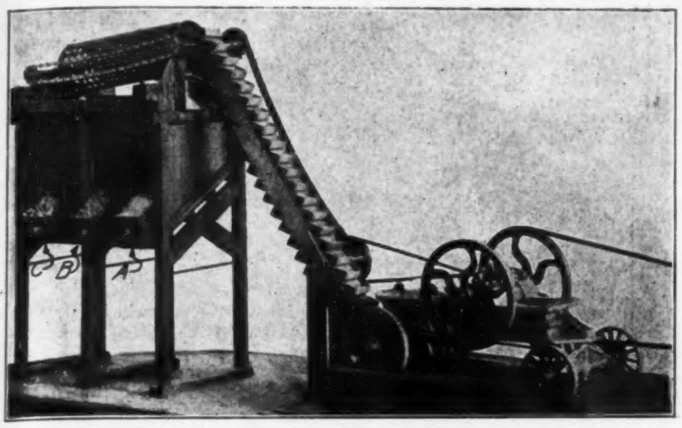


Fig. 1.—Model of portable crushing plant in operation.

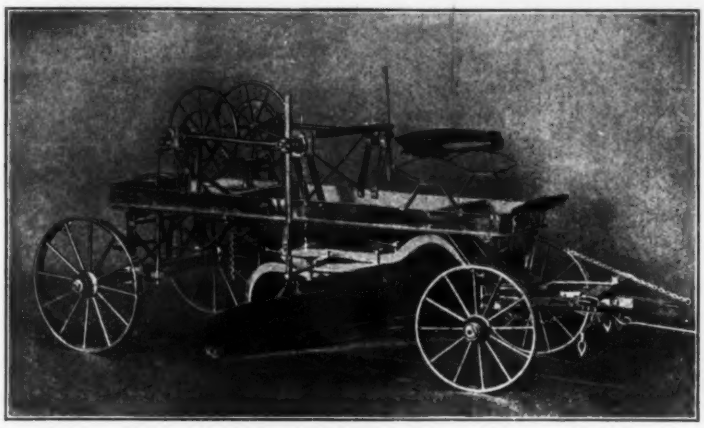


Fig. 2.—Model of road grader.

Paved Roads and Road-Laying Machinery*

Road Construction Illustrated by Models

Paved roads are sometimes advisable where there is heavy traffic. The materials which have been adapted to country roads during the past year are brick, asphalt block, and a small stone block extensively used in Germany and known as "kleinpflaster."

A good paving brick laid on a sand cushion with a substantial concrete foundation makes a road well adapted to both horse-drawn and motor traffic. The first cost of such a road is generally high, but this is largely offset by its durability and low maintenance cost.

Asphalt blocks are molded under pressure from sand, broken stone, and asphalt into rectangular blocks, which are laid on a concrete foundation somewhat in the same manner as brick. The asphalt blocks are more resilient than the brick and consequently freer from noise. They have as yet not been used to any great extent on the country roads of the United States. The small sett, or "kleinpflaster," pavement of Germany is as yet almost unknown in this country. A hard, tough rock, preferably basalt or diabase, is broken by machinery into cubes 3 to 4 inches in size. These are placed on a light sand cushion with a concrete or old macadam base as foundation. In Germany they are generally laid in an oyster shell or mosaic pattern, while in Hungary and Austria they are laid in rows at 45 degrees to the axis of the road. This pavement may be laid at a fairly low first cost, is not expensive to maintain, is neither noisy nor slippery, and is well adapted to mixed traffic.

CONCRETE ROADS.

Concrete roads are a comparatively new development in the effort to find a material which will successfully withstand both automobile and horse-drawn traffic. Concrete pavements were laid first in 1869 in Grenoble, France, where many streets are still paved with this material. In this country the first use of the concrete pavement was probably in Bellefontaine, Ohio, where several sections were laid in 1893 and 1894.

The largest use of concrete in building improved country roads at present is to be found in Wayne County, Mich. These roads are built of a 1:1½:3 mixture throughout, with a minimum thickness of 7 inches. The width of the surfaced roadway varies from 9 to 24 feet. The county road officials are very well pleased with this form of construction, and many miles are being built.

* From Bulletin 47 of the Office of Public Roads.

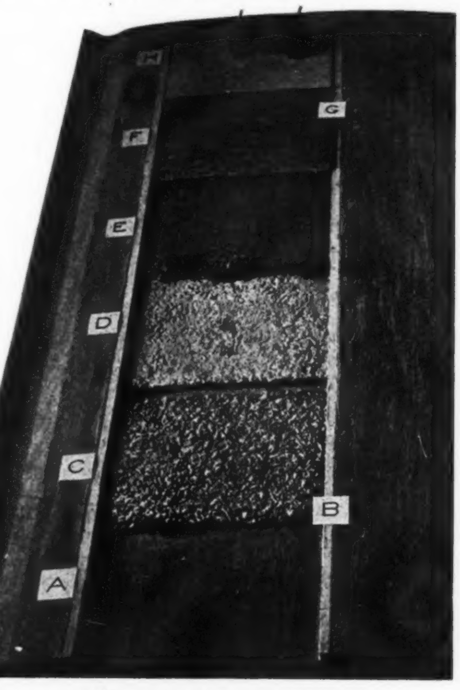


Fig. 3.—Model of a brick road.

In other cases a leaner concrete is used, and the surface is protected from the immediate impact of traffic by a cushion coat formed of some bituminous binder and sand, fine gravel, or screenings. This surface coating is renewed as often as may be necessary.

Attempts have also been made to produce a more resilient road surface by mixing a mineral oil with the cement. This form of construction is still in an experimental state.

Our engraving, Fig. 4, illustrates three types of concrete road, divided as follows: Sections *A*, *B*, and *C* in the first type; sections *D* and *E* in the second type; and section *F* in the third.

Section *A* represents the subgrade; section *B*, the oiled concrete, 6 inches thick, mixed in the proportion 1:1½:3½ and containing 5 pints of oil to each sack of cement (a traveled surface is here shown); and section *C*, a 2-inch loam covering, used to reduce evaporation while the concrete is curing. Section *D* represents the plain concrete, 6 inches thick, mixed in the proportion 1:1:3½ (the illustration shows a floated surface); and section *E* represents the 2-inch loam covering used to reduce evaporation while the concrete is curing. Section *F* shows the plain concrete, 6 inches thick, with a bituminous surface consisting of from one third to one half gallon of bituminous cement per square yard and sufficient torpedo sand or stone chips to provide a satisfactory wearing surface.

ASPHALT-BLOCK ROADS.

Figure 5 represents an asphalt-block road.

Section *A* shows the subgrade; section *B*, the concrete foundation and curb, mixed in the proportion 1:3:7, with a base 6 inches thick; section *C*, the cement mortar bed, one half inch thick, composed of 1 part of slow setting Portland cement and 4 parts of sand; and section *D*, the asphalt-block surface, covered with sand which has been screened through a one eighth inch mesh screen. This sand should be allowed to remain on the surface 30 days. The surface should then be swept clean.

Fig. 4.—Model showing three types of concrete road.

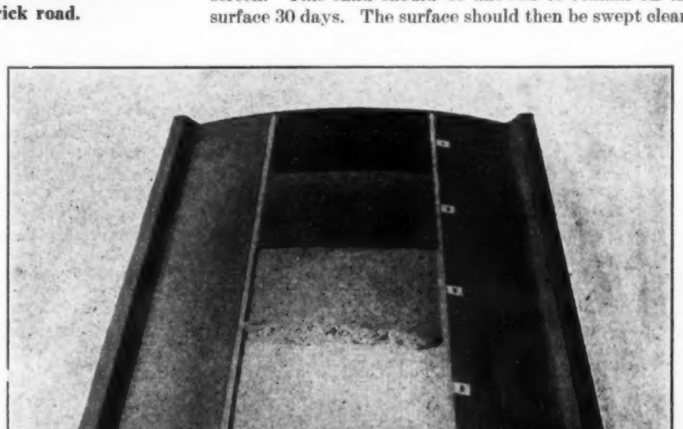


Fig. 5.—Model showing an asphalt-block road.

Section *E* represents the finished surface. The asphalt blocks are 5 inches wide, 12 inches long, and 2 inches thick.

BRICK ROADS.

Figure 3 illustrates the construction of a brick road where frost conditions are encountered, and differs from the other models in that the surface width is 14 feet, including the curb. The crown of the completed roadway is three eighths inch to the foot.

Section *A* illustrates the prepared subgrade for the foundation course; section *B*, the concrete curbing placed along the edges of the road; section *C*, a stone foundation 6 inches deep; section *D*, a concrete foundation 6 inches deep, which is often used in place of the stone foundation; section *E*, the sand cushion 2 inches deep, placed on top of the foundation previously described; section *F*, the surface before grouting; section *G*, the expansion joints; and section *H* illustrates the grouted brick surface ready for travel. In addition, a properly constructed mixing box is shown, illustrating the manner in which the grouting is prepared.

Many good roads were built before the invention of modern roadbuilding machinery, but modern machinery has done much to simplify the process and reduce the cost, especially of hand labor. The power-driven road roller has made possible the construction of a macadam road in a few days or weeks, where formerly traffic was required to make its way laboriously over the loose stones for months before the surface became even reasonably consolidated.

The steam roller was invented by M. Louis Lemoine, of Bordeaux, France. The French Government granted him a patent in 1859. The first English patent was granted to Mes rs. Clark and Bathe in 1863. The first steam road roller used in the United States was imported from England in 1868, and its first use was on the United States arsenal grounds in Philadelphia.

The stone crusher has greatly reduced the labor of preparing the broken stone. It was the invention of an American, Eli Whitney Blake, of New Haven, Conn., in 1858. He was a nephew of Eli Whitney, the inventor of the cotton gin. Mr. Blake's crusher was used first in Central Park, New York city, in crushing rock for concrete. In 1859 the city of Hartford, Conn., purchased one of these crushers for use in the improvement of its streets and roads. This was the first successful application of mechanical power to breaking stone for road-building purposes.

CRUSHER PLANT.

Figure 1, represents a portable stone-crusher plant.

Section *A* illustrates the stone screenings, commonly called "pea" size; section *B*, the second course of stone commonly called "nut" size; and section *C*, the first course, commonly known as "egg" size.

A stone crusher plant is indispensable in the construction of first-class stone roads and, if such work is to be done well and cheaply, the plant must be complete and conveniently arranged.

Sometimes the crusher can be located so near the quarry that the rock may be sent down grade in tram-cars and delivered to the mouth of the crusher by gravity thus rendering lifting by hand unnecessary. The crusher should be provided with an elevator and with screens for separating the material into proper sizes. The screens should be divided so that through the section near the upper end may pass fragments not exceeding one half inch in size, while the second section will allow the passage of stones less than 1¼ inches, and the third section will permit stones less than 2½ inches. Any larger stones will be forced through the opening at the end of the screen, from which they will drop into the tailings conveyor, to be crushed finally or eliminated from the work. The jaws of the crusher should be set so as to make as few tailings as possible.

When soft stones are being crushed, a dust jacket having a 1½ inch mesh may be placed over the first section to eliminate dust from the screenings. For receiving the various sizes of crushed rock, bins with slanting metal bottoms and sliding doors should be provided, so that the materials may be loaded into wagons by gravity.

Two types of crusher are commonly used, one the jaw crusher as shown in Figure 1, and the other the gyratory crusher. The jaw crusher is generally used for portable plants. In this machine one of the jaws moves backward and forward by means of a toggle joint and an eccentric, and the stone descends as the jaw recedes. As it returns it catches the stone and crushes it. The maximum size of the product is determined by the distance between the jaw plates at the lower edge.

The gyratory crusher consists of a solid conical iron shaft, supporting a heavy mass somewhat like an inverted bell. By means of an eccentric a rotary motion is given the shaft so that every point of its surface is successively brought near the surface of the "bell," and the rock caught between the shaft and "bell" is crushed.

The gyratory crusher will not produce as many flat pieces or tailings as the jaw crusher, because the stones must come in contact with two curved surfaces at the same time before they are broken.

ROAD GRADERS.

Figure 2 shows in miniature a machine which is used in building earth roads and in preparing the subgrade for macadam roads. The frame, which is on wheels, supports an adjustable scraper blade, the front end of which may be used to plow a furrow while the rear end pushes the earth toward the center or distributes it smoothly. The blade may be set at any angle or tilted either backward or forward.

In building the earth road with the road machine a furrow is first plowed with the point of the blade where the outside of the ditch is to be located. The blade may be made to penetrate hard or stony ground by elevating the rear end considerably and by using only the point of the blade for such plowing.

The team should be driven so that the point of the blade will follow the furrow made on the first trip, plowing a full furrow with the advance end of the blade and with the rear end dropped somewhat lower than before.

The machine should be guided gradually toward the middle of the road, so that it will move the earth previously plowed toward the center. This is done by slightly elevating the rear end of the blade to allow the earth to distribute under it and to give the necessary crown to the sides of the road.

It is advisable to use the machine when the ground is pliable, best of all in the early summer, in order to give the loose earth time to settle and pack before the fall rains. If the work is done in the fall, not more than 3 or 4 inches of loose earth should be put on at one working.

If the side of the road is covered with sod, this should be removed, and the earth from the side ditches should be used to replace it, if necessary.

What Are the Ten Greatest Inventions of Our Time, and Why?

Scientific American Contest: Third Prize Essay

By "Cherry Valley" (C. Cahall, Germantown, Philadelphia, Pa.)

The author of the essay published on this page was awarded the third prize, of the value of $50, by the judges in the Scientific American *Contest announced in the issue of August 2nd, 1913, of the* Scientific American.

In gaging the value of an essay on such a subject as here discussed, more weight must necessarily be laid upon the practical judgment and technical knowledge shown by the writer in his selection, than upon the literary form in which he presents his argument.

Mr. Cahall's selection of what are in his estimation the ten greatest inventions of the last twenty-five years will on the whole be indorsed by the great majority of his readers, though no two lists prepared by them might agree entirely among themselves or with his list.

I SUBMIT the ten following inventions as the ten greatest in importance and usefulness, which have been introduced or commercially developed within the past twenty-five years.

1. Edison's division of the electric current for incandescent light.
2. The transmission and transformation of the alternating electric current.
3. Nitrogen-compounds manufacture for agriculture and arts.
4. Recent modification of the internal combustion engine.
5. Flying machines.
6. Apparatus for the production of the X-ray.
7. Process work for reproducing illustrations.
8. The flexible photograph film.
9. The electric furnace.
10. Wireless telegraphy.

1. Edison's division of the electric current for incandescent lamps.

He saw in Philadelphia about 1879 a small arc light plant which had been taken about the country and exhibited as a scientific curiosity. With that mighty characteristic of his genius, Mr. Edison saw that to utilize the electric current for illumination of interiors, something different from the uncertain, high powered, arc light would have to be used. The current must be subdivided, and each lamp independent of the others. He finally settled upon a carbon filament in a vacuum tube as the most promising, but he found that the best vacuum at that time possible still contained enough oxygen to consume the carbon filament in a short time. Edison set to work to invent a method of producing a vacuum approaching a completeness the scientific world considered impossible. This being accomplished and after, literally, a world wide search for the best material for the carbon for the filament, Edison completed his lamp, conducted his current through a series of wires to make each lamp independent of the others, and finally opened his first public plant in New York in 1882, but it was not until within the last 25 years that it has been a practical and successful commercial institution.

2. The transmission and transformation of the alternating electric current.

When Mr. Edison introduced his electric lighting system he used the continuous current, and the first trolley lines were operated by the same current. For short distances, continuous current generated by dynamos, run by water power was satisfactory, but waterfalls were usually far distant from the cities where the current was most needed. Attempts to transmit the continuous current over long distances failed for two reasons, the great cost of the copper conductors, which had to be of great diameter to carry any current of large volume, and the great loss of the current by the transformation into heat as the current overcame the resistance of the conductor. Now the dynamos by a very slight alteration gave an alternating current, which has the property of being transmitted over small copper conductors in great quantity, without great loss of current. So that by sending the alternating current at the high pressure of twenty, or even fifty thousand volts, it was found to be quite practical to send it to the cities a hundred miles or more from the water falls. But this high voltage created another problem which had to be solved before these high voltage currents could be commercially successful. A very simple, yet wonderfully efficient invention called the transformer, was the result. This instrument, a sort of giant Ruhmkorff coil, "stepped up" the current from the dynamo to the transmission wires, and at the terminals "stepped down" again to lower voltage for the use of arc lighting the streets, the service of trolley lines, the running of motors in shops, and the lighting of incandescent lamps within doors. When the first great undertaking of this kind was begun—the utilizing of Niagara Falls—all these problems had to be worked out, and to Tesla has been generally given the credit of contributing more than any other toward their solution.

3. The production of nitrogen products from the air.

The wealth and comfort of nations depend largely upon the cost of living; the cost of living depends largely upon the cost of agricultural products; the cost of agricultural products depends largely upon the cost of maintainance of the productivity of the soil. Now soil analysis has proven that the three important elements which must be restored to the soil are potash, phosphorus, and nitrogen. The elements potash and phosphorus are still available from the earth's surface, but nitrogen is available, for fertilizing purposes, only through the agency of animal or vegetable life; hence its high cost. Yet there are millions and millions of tons of nitrogen in the earth's atmosphere, free to anyone who can make it available, and the beginning of the solution of this great problem has already been made, a problem among the greatest of importance which confronts the world today. The difficulty has been that nitrogen is a gas very reluctant to enter into combination with other elements to form soluble compounds.

To Professor Birkeland of the University of Christiania, Sweden, must be given the credit of attacking this great subject in a successful way. His factory, built in 1905, is run on the following plan. An immense arc light of enormous voltage is made to pass through a magnetic field which spreads it out into a great fan-shaped flame;

the atmosphere is forced through the flame, which causes the nitrogen and oxygen to unite, when it passes through reservoirs of water, forming nitric acid, which may be combined with the potash and so applied to the soil.

As the nitrate beds become smaller the cost of the natural nitrates will become more costly, and the process of the manufacture of artificial nitrogen compounds will be inevitably improved and cheapened, and it will take its place among the world's greatest manufactures.

4. Recent modifications of the internal combustion engine.

Although it has been 30 years since Dr. Otto devised his gas engine of that name, a very important modification of it was made within 25 years. The chief authority for the modification was Daimler, followed by Panhard and Levasser, who substituted for the gas a volatile oil such as gasoline, to be mixed with air from the carbureter, as a definite explosive gas, which was ignited by a hot tube or electric spark at the time of the compression. This modification allowed the use of a small, rapid revolving engine, of light weight and contracted space, which gave for the first time a practical motive power for vehicles. The automobile, one of the marvels of modern industry, the flying machine, with its high powered, yet light motor, and great ocean-going ships, using this motor, are transforming modern life, and yet they are the direct result of this modern modification of the internal combustion engine.

5. Flying machines.

It is a natural step from the motor to the flying machine. The flying machine is peculiarly an American invention. Professor Langley's classical experiments near Washington were the first scientific undertaking to solve the problem of flying through the air with a machine heavier than air. His experiments, formulated in the Langley's Law, clearly demonstrated the practicability of the aeroplane.

A few years later, working with gliding machines, the two Ohio brothers, Wilbur and Orville Wright, arrived at conclusions similar to those of Langley, but they had the practical inventive genius to construct a biplane with warping wings, which demonstrated to the world for the first time that men could fly at will through the air, with or against wind currents, in a machine heavier than air.

If military necessity has driven France and Germany to advance faster than America in the practical development of the flying machine, the courts of these same countries have granted the Wright brothers their justifiable claims to priority.

6. The apparatus for producing the X-ray.

All of the elements of the X-ray apparatus were known before Professor Röntgen used them for a definite purpose. It is true that it was by pure accident that Professor Röntgen discovered that a photograph plate exposed to the cathode rays of a vacuum tube, became light struck through bodies opaque to the rays of light but pervious to cathode rays. But the fact would have escaped the notice of any observer less great than Röntgen. He was studying the cathode rays, and to his scientifically equipped mind there was nothing of the impossible in the idea that substances opaque to the shorter rays of light—the one sixty-fourth thousand of an inch—may be easily penetrated by rays enormously less than these.

The usefulness of the X-ray apparatus became at once an invaluable aid in diagnosis to the surgeon, showing the exact condition of broken or dislocated bones, the exact location of foreign bodies in the tissues, so that they may be successfully removed, even from the brain itself; for the physician; the position and dimensions of the heart, the liver, the presence of aneurisms and tumors, cavities in the lungs, stone in the kidney, and after the administration of bismuth, the outlines and malpositions of the hollow viscera. It has become a standard treatment in certain skin affections, and as an after treatment following the removal of cancer. It is a necessary equipment of every modern hospital. No one has ever disputed Professor Röntgen's position as the first user of the X-ray in photography, and he was awarded the Nobel prize in 1901.

7. Process work for reproducing illustrations.

One has but to look into any old book or magazine to see the paucity of illustrations. The reason of this was that each illustration had be hand engraved on steel or cut in wood, both tedious and expensive, and totally out of the question for the use of frequent publications, such as newspapers.

The accuracy and speed of the photograph has been called upon here, with the result that "half tone," and even three-color reproduction are so rapidly, cheaply, and satisfactorily done, that even the daily papers can afford to illustrate their text so voluminously, and within a few hours after the photograph has been taken. The process is based upon the fact that a gelatine, sensitized film upon a zinc block, exposed to light through a negative shrinks or swells according to the degree of light. The film is then developed, inked and subjected to an acid bath which eats away the metal unprotected by the ink.

The refinement of this process, that of "half tones," is the use of a screen of minute dots or lines ruled upon glass, between the negative and the prepared zinc block. This permits the use of such photographs that do not present the strong contrasts of light and shade. Mr. Fredrick Eugene Ives of Philadelphia was the inventor of the "half tone" process, as he was also of the first practical blocks for three-color printing.

8. The flexible photograph film.

The development of the flexible transparent film in 1888 by the Eastman Kodak Company was the most important advance in photography, for it made it not only possible for travelers and explorers to take with them sufficient rolls of films for long journeys without prohibitive weight and to bring back to civilization pictures of life of inestimable value, but it made it at last possible for the rapid development of that great modern institution, the moving picture.

And the value of moving pictures is scarcely yet appreciated. So far they have been used chiefly for amusement, but they are destined to prove of powerful educational value.

9. The electric furnace.

When an abundance of electricity was made available by the Niagara Falls Electric Plant, the electric furnace became possible. It had long been known that many electro-chemical reactions needed but an intense heat. This the electric arc furnishes. At once manufacturers went to Niagara or vicinity to utilize it.

Already a fine grade of amorphous graphite is manufactured there, there is the possibility of artificial gems being produced by this intense heat under great pressure, but the great industry it has given rise to has been the manufacture of aluminium. This metal, once a rare and costly curiosity, is now being manufactured by the thousands of tons at near the cost of copper. Its uses are being multiplied daily, and it is destined to be the most useful and economical of metals, for its distribution as alumina is world wide and unlimited in quantity.

The manufacture of aluminium is now a very simple process, owing to the discovery by Charles M. Hall, while a student in college, that the mineral cryolite will absorb alumina to one fourth its bulk.

The heat of the electric current fuses this mass and the electrolitic action of the current deposits the metal aluminium at one of the poles. By the addition of aluminia the process becomes continuous.

10. Wireless telegraphy.

Just as the elements of the X-ray machine were known before Professor Röntgen, so the elements of wireless telegraphy were known before Marconi.

In 1886 Dr. Hertz discovered waves of ether of greater amplitude than light waves and called the attention of scientists to them for their possible use in wireless telegraphy.

The sending of the messages was simple enough, the difficulty was in catching them at the receiver. This was made possible by the invention of the "coherer" by Dr. Branly in 1890. Now all the essential elements for successful wireless were known. Indeed Sir Oliver Lodge in 1893 in England and Professor Popoff in 1895 in Russia did send wireless messages over short distances through the air.

But Marconi about 1894-96 took all these crude and incomplete models, invented a practical coherer of great simplicity and sensitiveness, and added the very essential adjunct, the long air wires.

With this apparatus he within a year sent his messages across the English Channel, and in 1901 received the first trans-Atlantic wireless between England and Newfoundland. So Marconi justly enjoys the honor of being called the real inventor of Wireless telegraphy.

It is needless to dwell upon the value and importance of wireless telegraphy. Every reader from his own knowledge, will place it high among the great inventions of modern times.

Our Universities and Industrial Research*

By A. D. Little

In view of the evidence offered by Germany of the far-reaching benefits resulting from the close co-operation which there obtains between the university laboratory and the industrial plant, it must be admitted with regret that our own institutions of learning have, speaking generally, failed to seize or realize the great opportunity confronting them. They have, almost universally, neglected to provide adequate equipment for industrial research, and, which is more to be deplored since the first would otherwise quickly follow, have rarely acquired that close touch with industry essential for familiarity and appreciation of its immediate and pressing needs. There are happily some notable exceptions.

Perhaps foremost among them stands the Massachusetts Institute of Technology with its superb engineering and testing equipment, its Research Laboratory of Applied Chemistry and the meritorious thesis work of its students in all departments. The Biological Department has been especially active and successful in extending its influence into industrial and sanitary fields, while unusual significance attaches to the motor vehicle studies just concluded and the more recently inaugurated special investigations in electricity, since both were initiated and supported by external interests. About two years ago the Institute brought vividly before the community the variety and extent of its wide-spread service to industry by holding a Congress of Technology, at which all of the many papers presented recorded the achievements of the Institute alumni.

The Colorado School of Mines, recognizing that $100,000,000 a year is lost through inefficient methods of ore treatment, has recently equipped an experimental ore dressing and metallurgical plant in which problems of treatment applicable to ores of wide occurrence will be investigated. The Ohio State University has established an enviable reputation for its researches in fuel engineering. Cornell has been especially alive to the scientific needs of industrial practice, and a long experience with technical assistants enables me to say that I have found none better equipped to cope with the miscellaneous problems of industrial research than the graduates of Cornell. It may be in fact stated generally that the quality of advanced chemical training now afforded in this country is on a par with the best obtainable in Germany, and that home-trained American youth adapt themselves far more efficiently to the requirements and conditions of our industries than do all but the most exceptional German doctors of philosophy who find employment here.

Several of the great universities of the middle west, notably Wisconsin and Illinois, have placed themselves closely in touch with the industrial and other needs of the community and are exerting a fundamental and growing influence upon affairs. In the East, Columbia has recently established a particularly well equipped laboratory for industrial chemistry and is broadening its work in this department.

The Universities of Kansas and of Pittsburgh are carrying forward an especially interesting experiment in the operation of Industrial Research Fellowships supported by the special interests directly concerned. These fellowships endow workers for the attack of such diverse subjects as the chemistry of laundering, the chemistry of bread and baking, that of lime, cement and vegetable ivory, the extractive principles from the ductless glands of whales, the abatement of smoke nuisance, the technology of glass, and many others. The results obtained are intended primarily for the benefit of the supporters of the individual fellowships but may be published after three years. The holder of the fellowships receives a proportion of the financial benefits resulting from the research, and the scale of sums allotted has progressively risen from $500 a year to $2,500 and even to $5,000. While some doubt may reasonably be expressed as to the possibility of close individual supervision of so many widely varying projects the results obtained thus far seem entirely satisfactory to those behind the movement.

Research in the textile industries has been greatly stimulated by the various textile schools throughout the country, of which the Lowell Textile School with its superb equipment is perhaps best known. The fermentation industries have been brought upon a scientific basis largely through the efforts of the Wahl-Henius Institute at Chicago and other special schools.

There is no school of paper making in the country and one of our most urgent industrial needs is the establishment of special schools in this and other industries for the adequate training of foremen who shall possess a sufficient knowledge of fundamental scientific principles and method to appreciate the helpfulness of technical research. The Pratt Institute at Brooklyn has shaped its courses admirably to meet this demand.

* Extracts from Presidential Address before the American Chemical Society.

Speed Control by a Rotary Fan.—In a patent 1,068,097 Rueben B. Benjamin, of Chicago, Ill., assignor to Benjamin Electric Manufacturing Company has patented an explosive engine governor for automobiles in which is provided a controlling mechanism by which the carbureter of the engine may be set to feed a definite amount of fuel to maintain the speed of the engine at a predetermined point. The controlling mechanism includes a rotary fan driven at a speed corresponding to that of the motor and having a movable member operated by variations in air pressure on the blades of the fan due to variable speeds of the fan. This movable member operates upon the throttle of the carbureter.

Fig. 1.—Manufacture of plates and dishes.

Circular objects, such as dinner plates, round dishes of all kinds, etc., are "turned" to shape on rapidly rotating platform, with the aid of suitable templates.

Fig. 2.—Decorating by metachromotype.

The metachromotypes are laid upon the china, moistened with water, rolled tight, and the paper drawn off. The article is then fired in a furnace at about 800 deg. Cent.

Fig. 3.—The process of gold stamping.

Certain gold ornamentations are most satisfactorily produced by a process known as stamping, but gold is generally applied with a brush.

Porcelain

Its Manufacture and Decoration

By Dr. Alfred Gradenwitz

Though Germany, the cradle of European porcelain industry, has always been among the countries producing some of its most beautiful creations, the general stagnation of German decorative art in the nineteenth century left its mark also on this field of industry. While the Royal Manufactories and some private works were successful in keeping up the traditions of careful work and high quality, the strong life formerly pulsating in this productive and creative industry seemed definitely to have gone out.

However, this temporary sterility at length resulted in a reaction on the part of the leading artists, and when, in 1900, the Copenhagen Porcelain Factories celebrated unprecedented triumphs at the Paris World's Fair, they definitely found their way back to their former prosperity and leading position. In fact, the last ten years have witnessed a powerful advance in the German porcelain industry, both in quantity and in the artistic quality of products.

By the courtesy of a manufacturing firm of Selb, Bavaria, we are enabled to illustrate and describe the various departments of their works, which are claimed to be the largest factories of high-grade porcelain.

The raw materials of porcelain, as is well known, are mainly kaolin or porcelain clay, feldspar and quartz. A pure, white and spotless mass, of course, can only be made from pure raw materials, free from iron. Such perfect raw materials, however, are of rather rare occurrence. German factories use, for their best products, nearly exclusively the kaolin of Zettlitz, Bohemia, and Swedish feldspar and quartz.

The enamel of porcelain mainly consists of the same materials as the mass proper, except that it contains a higher percentage of the flux required to produce the vitreous glazing; it is generally prepared from ground porcelain fragments, to which feldspar, chalk or dolomite are added.

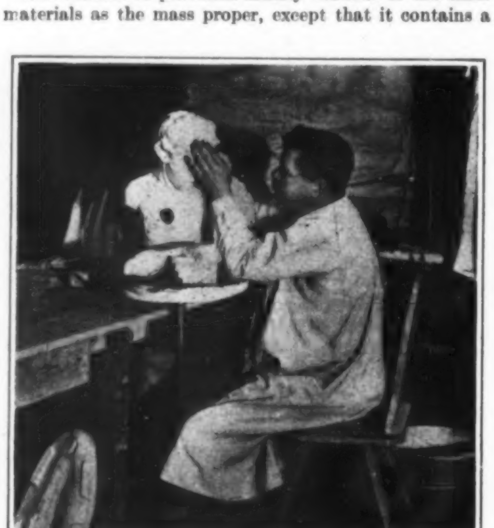


Fig. 4.—In the statuary department.

Statues are molded in a number of part molds, and the seams left at the places where molds join are carefully gone over by hand.

The effect of each of the raw materials is as follows:

Kaolin is the essential ingredient which gives to its mass its plastic character. On the other hand, it suffers no appreciable shrinkage or deformation under the action of high temperatures, but is merely hardened and consolidated thereby.

Feldspar and quartz tend to diminish the plasticity of kaolin, and aid in the drying process. Feldspar in the fire melts into a milky glass fluxing together the refractory structure of the clay. It also partially dissolves the quartz at higher temperatures.

Chalk and dolomite exert effects similar to those of feldspar, acting as fluxes and a surplus of such fluxes as present for example in porcelain enamel, results in a glassy, shining surface.

The first stage in the treatment of these raw materials consists in crushing and mixing them most intimately by means of special machines. Feldspar and quartz are first crushed between grindstones, and then in ball mills iron cylinders containing loose flint balls. The material is here ground into a fine powder or, if it be mixed with water, into a thin pulp. Kaolin is then added in large stirring troughs. The thin paste thus obtained is passed through filter presses, and there deprived of the bulk of its water. On leaving the press, the mass is stored in cement lined cellars, and finally just before use, is subjected to beating and pressing in

Fig. 5.—Charging a furnace.

Each porcelain article is inclosed in a separate protecting box, and these boxes are stacked up in piles in the firing furnace.

Fig. 6.—Casting china.

The plastic mass is reduced to a thin pulp by the addition of water and alkali, and in this form can be cast in absorbent molds.

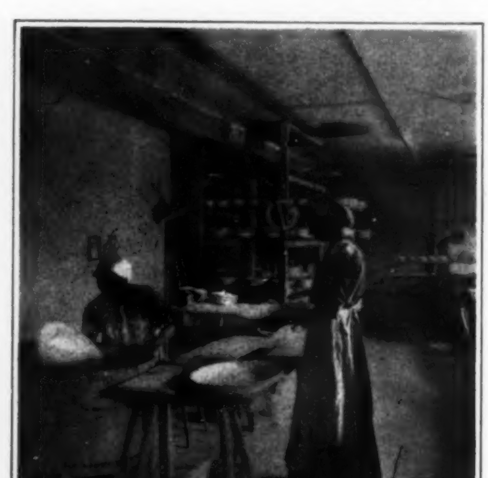


Fig. 7.—In the enameling department.

The articles are dipped in a thin liquid glaze. The porous porcelain absorbs the glaze and remains covered with a coating subsequently hardened in the furnace.

special machines, to thoroughly mix the ingredients and render the mass homogeneous throughout.

The manufacture of porcelain objects is effected by three different processes, viz.: by shaping, casting and dye-pressing.

In *shaping* (Figs. 1 and 4), the porcelain mass is either given the desired form free-hand on the turning disc or worked by the aid of plaster molds, with wood and iron patterns.

In *casting* (Fig. 6), the plastic mass is liquefied by the addition of water and alkalies, so as to form a pulp, and is poured into plaster mo'ds. The porous plaster absorbs part of the water and deposits on the walls of the mold a thin layer of the porcelain mass.

Dye-pressing of porcelain objects is done in steel molds or matrices, the mass being to this effect dried and rubbed in with kerosene oil.

The molded objects having been dried some days, are baked at about 800 deg. Cent. in the "biscuit" furnace. This solidifies their structure and results in a product comparable with earthenware, which is still very brittle, sounds like earthenware when struck, and strongly absorbs water. The latter property is utilized in applying the enamel (Fig. 7). The articles to be enameled are immersed in a very liquid glazing pulp where they absorb part of the liquid, so that a thin layer of glaze is deposited upon their surface.

After being thus coated with enamel, the objects are taken to the firing furnaces (Fig. 5). Each article is inserted in a fireclay box to protect it against the direct action of the flames. During the firing of the crude porcelain the feldspar melts and dissolves part of the quartz, permeating all channels and pores of the clay structure, the components of the enamel likewise melt, generally somewhat later than those of the main mass, but much more completely than the latter, i.e. to a more perfectly liquid mass, coating the whole object with a vitreous layer.

Since the enamel is liquefied in a baking furnace, provision should be made to prevent articles from adhering to the fireclay boxes. Thus the bottom of plates and cups should be freed from enamel. This is why all porcelain objects have some rough part where the glazing is removed. Moreover, the mass softens considerably in firing and special arrangements are required to prevent deformation. Cups are, e.g., baked on round little plates, so as not to lose their circular shape.

The distribution of material in vases, tureens and other large objects must be carefully adjusted otherwise they are apt to give way in the furnace. Delicate statuary must be upheld by special supports.

The temperature in the firing furnace is extremely high, being intermediate between 1,400 and 1,450 deg. Cent., that is, sufficient to melt practically all metals, with the exception of platinum. Since this temperature cannot be measured by the usual means special methods are required to recognize the end of the operation.

A process formerly in use and which is still employed by many porcelain factories consists of providing a sample cup, to be removed from the furnace after a given time. According to the condition of this cup, baking is continued or stopped. Temperatures are now generally determined by means of "liquidation" cones, i.e. small pyramids of different grades of porcelain, which fuse at definite temperatures. The softening and bending over of each cone corresponds to some definite temperature.

The white, finished porcelain should primarily have the following three properties: It should be transparent in thin fragments, the mass should be absolutely white and spotless, and the enamel should be of a glassy, reflecting surface.

If the porcelain be baked without enamel, its surface is (according to the composition of the mass) rough or of a dull silk polish. Objects baked without enamel are known as "biscuit."

For the *painting* of porcelain there are mainly two methods in use, viz.: painting below the enamel (with subsequent treatment in a sharp fire) and painting over the enamel (firing in a muffle furnace).

According to the former method, the colors are applied directly on the mass baked in the biscuit furnace. The subsequent firing of the porcelain results in an intimate fusing of the porcelain with the colors protected by the overlying layer of enamel. The color scale suitable for this process is of course rather limited, there being only a few metal oxides able to stand the high temperatures of porcelain furnaces. However, the color effects, thanks to the overlying enamel, are wonderfully soft, and another advantage is that these colors are absolutely imperishable and cannot be worn out.

Another "sharp-fire" painting process consists of applying to the finished porcelain colors similar to those used in the above process and exposing it once more to a sharp fire. The colors are then made to melt into the enamel from above and to unite with it intimately. Cobalt pigments are mainly applied by this process.

In the muffle-furnace process, the white ready-baked porcelain is painted on and subsequently baked at a temperature of about 800-900 deg. Cent. The pigments used in this case are metal oxides, mixed with a glazing of much lower melting point than porcelain enamel. At a temperature of 800-900 deg. Cent., these pigments melt on the enamel. Since hand painting is a very costly and difficult process, a number of mechanical printing processes have been desired. Metachromotypes made with ceramic colors are transferred to the porcelain and baked into the mass (Fig. 2). Another process consists of preparing engraved steel plates, filling the ornamental pattern with pigments, and transferring these pigments on fine tissue paper and thence on the porcelain. Gold is generally applied by means of a brush, although many gold ornaments are deposited upon the porcelain by stamping (Fig. 3).

A new process for decorating porcelain consists in etching portions of the surface with fluoric acid and gilding the whole. The contrast of the polished and dull gold parts produces the most delicate effects, comparable with those of high class engraved and chased work.

A last finish may be applied to the porcelain by polishing and grinding, thus smoothing down any rough parts.

Modern Methods of Measuring Temperature—II*

Electric and Other Thermometers for Use in Industrial Operations

By Robert S. Whipple

Concluded from Scientific American Supplement No. 1975, Page 299, November 8, 1918

Resistance Thermometers.—Sir William Siemens was the first to suggest (in 1871) that the change in the electrical resistance of a wire with temperature might be employed as a means of measuring temperature. Electrical resistances can be measured with great accuracy, and the method has become the most accurate, and in many ways the simplest, for determining temperature. Unfortunately, Sir William Siemens wound the platinum wire, of which he was measuring the changes of resistance, on a fire-clay cylinder and used an iron tube to protect the coil from the furnace gases. At high temperatures these gases penetrated the iron tube and attacked the platinum. The silicates in the fire-clay cylinder had also a deleterious effect on the platinum, and caused variations in its resistance, thus rendering the thermometer unreliable.

* Paper read before the Institute of Mechanical Engineers.

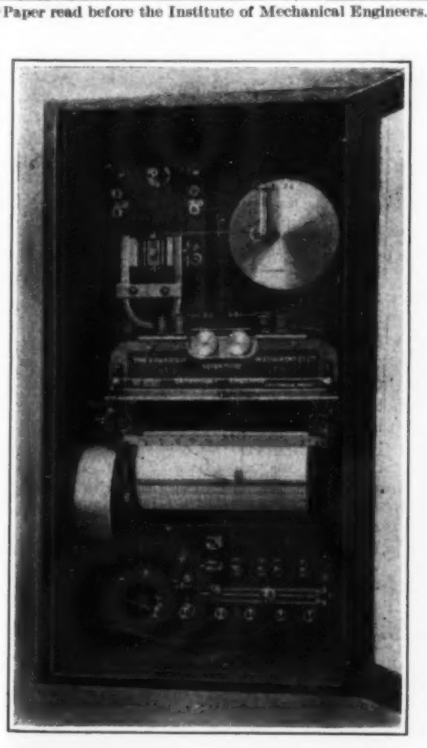


Fig. 16.—Callendar temperature recorder.

It was not until 1887 when Callendar and Griffiths worked out the theory of the resistance thermometer, and designed the method of mounting the coil on a mica frame, that it proved itself to be a reliable method of measuring temperature. Callendar showed that if the platinum wire is supported on a mica frame, in section that of a cross with equal arms, there is perfect insulation without any cause of alteration. He also showed that all joints in the thermometer itself should be made by fusion because metallic solderings are volatile and attack platinum. Callendar's and Griffiths' researches[1] show that the platinum resistance thermometer, if protected from strain and contamination, is free from zero changes over a range of 0 to 1,200 deg. Cent., and that it always gives the same indication at the same temperature, and this has since been confirmed by many observers.[2] Callendar also showed that different platinum wires agreed in giving the same value for any temperature on the platinum scale, although they differed considerably in the values of their temperature coefficient.

Callendar pointed out that if R_0 denoted the resistance of the thermometer coil at 0 deg. Cent. and R_1 its resistance at 100 deg. Cent., a temperature scale may be established for the particular wire which may be called the scale of platinum temperatures, such that, if R be the resistance of the coil at any temperature t on the gas scale, the temperature on the platinum scale will be $\frac{R-R_0}{R_1-R_0} + 100$. For this quantity he employs the symbol pt, its value depending on the sample of platinum chosen.

[1] Phil. Trans. Royal Society, vol. 178, pages 160-230, 1888, and "Notes on Platinum Thermometry," *Phil. Mag.* Feb. 1899.

[2] "On the Determination of High Temperatures by means of Platinum-resistance Pyrometers," Heycock and Neville, *Journal of Chem. Soc.*, 67, pages 160, 1024. 1895.

"A comparison of platinum and gas thermometers made at the Bureau International des Pois et Measures," Chapuis and Harker, *Phil. Trans.* 1900.

"Platinum Resistance Thermometry at High Temperatures," C. W. Waidner and G. K. Burgess, *Bulletin of the Bureau of Standard*, Vol. VI, No. 2.

In order to reduce the temperatures on the platinum scale t to the gas scale it is necessary to know the law connecting t and pt. They are of course identical at 0 deg. and 100 deg. Cent., and experiment has shown that the formula

$$t - pt = \delta\left\{\left(\frac{t}{100}\right)^2 - \frac{t}{100}\right\}$$

when δ is a factor depending on the purity of the wire for making the thermometer, expresses the relationship between them in other parts of the scale.

Fig. 17.—Whipple temperature indicator.

Fig. 18.—Whipple-Féry pyrometer.

The $t-pt$ curve being a parabola, it is only necessary to determine the resistance at three different temperatures in order to ascertain the value of δ, and thus to standardize the thermometer completely. The three

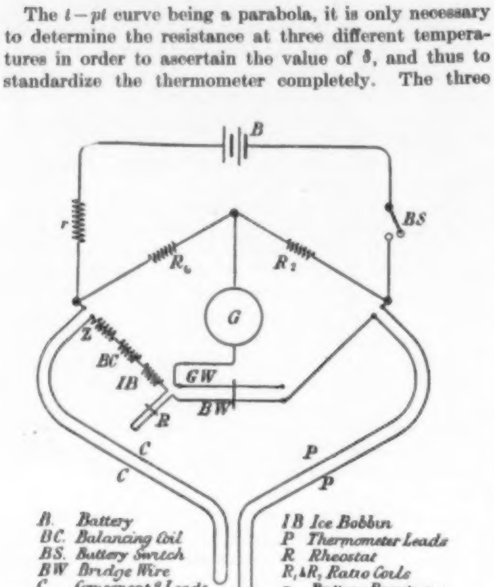


Fig. 19.—Diagram of bridge arrangement (Wheatstone) for temperature measurement.

temperatures usually employed are:—0 deg., 100 deg. and 444.70 Cent. (the boiling-point of sulphur).

As generally constructed the platinum-resistance thermometer consists of a fine platinum wire (0.008 inch in diameter) wound on a mica frame, connected by stout silver or platinum leads to terminals in the head of the thermometer. Two similar leads, but unconnected to the coil, pass through the whole length of the thermometer, and act as compensating leads. The method by which they compensate will be explained later.

The resistance of the thermometer is usually measured by the ordinary Wheatstone Bridge arrangement, although the Kelvin Double Bridge is sometimes used with thermometers of very low resistance. Modifications of the original differential arrangement suggested by Siemens, and the deflection method of Callendar's have been revived in some recent industrial instruments.

The methods of measuring temperature to a very high degree of precision are outside the scope of this Paper, but reference will be found to them in Dr. Burgess's book[3] which also contains a full bibliography of Papers on the subject.

The diagram, Fig. 19, shows the Wheatstone Bridge or "Null" method of measuring the resistance of a thermometer. The ratio coils are adjusted to equality and to approximately the mean resistance of the thermometer. The thermometer and its connecting leads are placed on one side of the bridge and are balanced by the compensating leads, the variable resistance coils, bridge wire and the rheostat placed on the other side.

The compensating leads are mounted in the same protecting covering as the leads attached to the thermometer, and are under exactly the same temperature conditions. Thus any changes in resistance of the leads owing to changes in their temperature must affect each side of the bridge equally, and the balance point of the system will remain unchanged. Callendar and Griffiths designed a simple combined form of galvanometer and bridge in which the resistance of the thermometer was balanced with coils and bridge wire, the value of the resistance being given directly in temperature on the platinum scale. Fig. 17 shows a modified form of this indicator,[4] constructed by the Cambridge Scientific Instrument Company, in which a long bridge-wire takes the place of the multiple coils and short bridge-wire, and in which the readings are given directly on the gas scale. As showing the possibilities of an industrial thermometer outfit of this type, it may be mentioned that it is possible to read temperatures anywhere between 0 and 1,200 deg. Cent. to an accuracy of 0.1 deg. Cent. As the method is a "Null" one the readings are independent of the voltage of the battery.

Several direct-reading indicators have recently been introduced. A principle frequently made use of is that of the ohmmeter, in which the variable resistance of the thermometer is balanced against a fixed resistance by means of the deflection of a galvanometer coil carrying currents from circuits shunted round the two resistances in question. One of the most successful of these instruments is the Harris-Paul Indicator,[5] which is a two-coil ohmmeter and which reads in gas scale degrees on all ranges, its accuracy also being independent of the voltage of the battery. The Leeds and Northrup Company, of Philadelphia, and the Cambridge Scientific Instrument Company also make deflectional instruments. Recorders for recording automatically the temperature can also be arranged to work on either the balance or deflectional methods.

The first and most successful recorder is due to Callendar. It consists of a Wheatstone Bridge, Fig. 16, in which the movement of a slider along a bridge-wire is automatically effected by sensitive relays worked by the current passing through the galvanometer between the bridge arms. The moving coil of this galvanometer carries an arm which makes contact on one side or the other of a small platinum-rimmed wheel rotated by clockwork. When contact is made, a relay circuit is connected through one or other of two electro-magnets

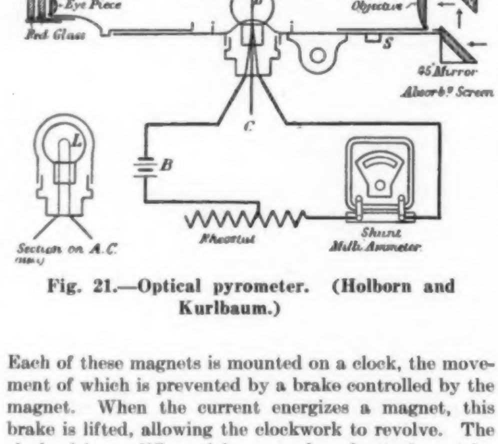


Fig. 21.—Optical pyrometer. (Holborn and Kurlbaum.)

Each of these magnets is mounted on a clock, the movement of which is prevented by a brake controlled by the magnet. When the current energizes a magnet, this brake is lifted, allowing the clockwork to revolve. The clocks drive a differential gear and cord attachment by means of which the slider on the bridge-wire is pulled in one direction or the other, depending on the brake lifted. The movement of the slider tends to restore the electrical balance. A pen is rigidly attached to the slider so that all its movements are recorded on a chart placed round a clock-driven rotating drum. The Leads and Northrup Company have introduced some modifications in this recorder, making it more rapid in showing and recording changes in temperature. The boom of the galvanometer is automatically gripped at intervals of ten seconds, and the principal mechanical power for operating the recorder is provided by an electric motor. This recorder has shown itself rapid in action, and like the Callendar gives rectangular ordinates, and the mechanism is independent of the galvanometer system.

Both these recorders are extremely elastic in the temperature ranges over which they may be used. If desired, the total range across the paper (200 and 225 millimeters respectively) may be made equal to either 5 deg., 50 deg., 100 deg., or 1,000 deg. Cent. with any intermediate range, by simply varying the resistance of the thermometer or bridge wire. The same instrument can thus be employed for either a piece of delicate research work or the every-day purposes of a factory.

Both the Cambridge Scientific Instrument Company and Siemens and Halske have developed deflectional recorders for use with resistance thermometers, the former firm employing their thread recorder, the latter their recording milli-voltmeter. In neither case have these recorders any advantage (except a slight reduction in cost) over the Callendar or Leeds and Northrup recorders, whereas they have the disadvantages of greatly contracted scales, and the necessity for adjusting the battery voltage at least once daily.

Thermo-electric and resistance thermometers both have a distinct upper limit of temperature beyond which they should not be employed. In the case of the resistance thermometer the limit is 1,200 deg. Cent., above which temperature the mica frame disintegrates. The thermo-couple can rarely be employed above 1,400 deg. Cent., because of the impossibility of finding a gas-tight protecting envelope that will last above this temperature. The porcelain tubes made by the Royal Berlin Porcelain Manufacturing Company are on the whole the most satisfactory, but even the glaze on these tubes gives way

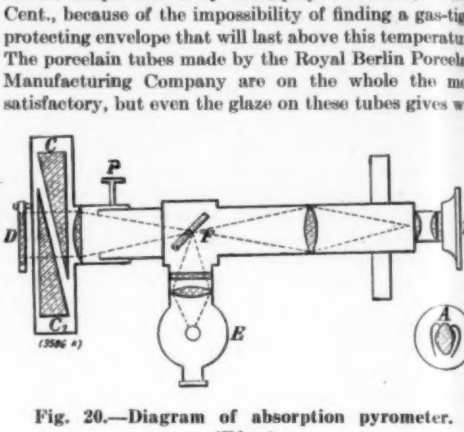


Fig. 20.—Diagram of absorption pyrometer. (Féry.)

at about 1,400 deg. Cent. The Royal Berlin Porcelain Manufacturing Company have comparatively recently introduced a tube of a somewhat different material called "Marquardt," which will resist temperatures up to 1,700 deg. Cent. (approximately the melting-point of platinum). Unfortunately, tubes made of this material are very brittle and great care must be taken in handling them, especially in allowing them to cool slowly. Tubes made of fused quartz are also employed, but it will be found that these tubes soon devitrify and become brittle if used continuously at a temperature of 900 deg. to 1,000 deg. Cent. They have also the drawback of inherent mechanical weakness. The temperatures reached in many modern manufacturing processes are also so high that there are no satisfactory materials that can be employed as the thermo-couple elements.

Optical and Radiation Pyrometers.—The foregoing considerations show the importance of being able to measure temperature without bringing the pyrometer into immediate contact or proximity with the hot body. Although Ed. Becquerel had proposed (1864) to refer the measurement of high temperatures to the measurement of the intensity of red radiations emitted by incandescent bodies, yet it was not until Le Chatelier[6] invented his optical pyrometer in 1892 that any really satisfactory attempt was made to determine the temperature of a hot body by measuring the radiations emitted by it. Before discussing his pyrometer in detail, it may be of service to consider briefly the problem of measuring the temperature of hot bodies by estimating the energy they radiate either in the form of visible light or from the thermal effects of the long infrared waves. The intensity of the light emitted by a hot body varies immensely with the temperature,[7] and therefore, at the first glance, one would assume that the easiest way to measure a temperature would be to compare photometrically the light emitted by the hot body with that emitted by a second hot body at a definite temperature. This would be the simplest way of doing so, if all bodies at the same temperature emitted the same amount of light, but unfortunately such is not the case, the light, for example, from incandescent iron and carbon being much greater than that from porcelain or platinum at the same temperature.

Kirchoff first propounded the idea of a "black body" as being a body which would absorb all radiations falling upon it and would neither reflect nor transmit any. He also showed that the radiation from such a black body is a function of the temperature alone, and was identical with the radiation inside an enclosure, all parts of which have the same temperature. It has already been men-

[3] "The Measurement of High Temperatures," pages 212–218, 470–471. In this connection it may be mentioned that Principal E. H. Griffiths successfully made differential temperature measurements between the freezing-points of two liquids to one-millionth of a degree Centigrade by means of resistance thermometers and a sensitive bridge.

[4] "Temperature Indicator," by R. S. Whipple, *Proc. Physical Society*, London, vol. 18, page 235. 1902.

[5] Made by Mr. R. W. Paul. See "Measurements of High Temperatures," *loc. cit.*, pages 218 to 221.

[6] "On the Measurement of High Temperatures," H. Le Chatelier, *Comptes Rendus*, vol. 114, pages 214–216. 1892.

[7] If the intensity of the right light $\lambda = 0.656\,\pi$ emitted by a hot body at 1,000 deg. Cent. is called 1, at 2,000 deg. Cent. the intensity will be 2,100 times as great (See C. W. Waidner and G. K. Burgess, "Optical Pyrometry." (*Bulletin No. 2 of the Bureau of Standards.*)

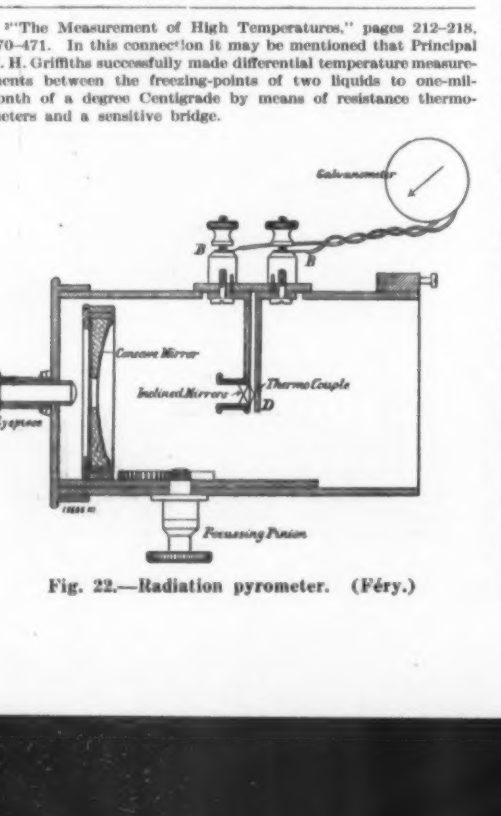


Fig. 22.—Radiation pyrometer. (Féry.)

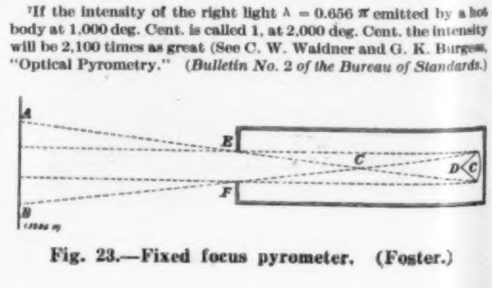


Fig. 23.—Fixed focus pyrometer. (Foster.)

tioned that iron, porcelain, etc., do not emit the same amount of light when heated to the same temperature. If, however, they are heated inside a black body—and the ordinary commercial furnace practically fulfils black-body conditions—then they will all emit the same radiation, and if looked at through a small opening in the furnace they will appear of uniform brightness. It is thus possible with a furnace fulfilling black-body conditions to study the energy radiated as compared with the temperature.

The temperatures indicated by a radiation pyrometer that has been calibrated under black-body conditions are known as black-body temperatures. It will be found that the apparent temperature of any material when away from black-body conditions will always bear a fixed relationship to its true temperature. For example, the black-body temperature of a piece of iron at 1,200 deg. Cent. will be 1,140 deg. Cent. and that of porcelain at the same temperature 1,100 deg. Cent.[8]

It is thus very important to know the relationship between the radiation emitted and the temperatures, and a great deal of mathematical and practical work has been devoted to this object.[9]

Stefan was the first to state that the energy radiated was proportional to the fourth power of the absolute temperature. Boltzmann later propounded the same law from thermo-dynamic reasoning assuming the existence of light pressure. This law has since become known as the Stefan-Boltzmann radiation law and may be stated as follows:—

The total energy radiated by a black body is proportional to the fourth power of the absolute temperature, or,

$E = \sigma (T^4 - T_0^4)$ when E is the total energy radiated by the body at absolute temperature T to the absolute temperature T_0 deg., and σ is a constant depending on the units used. This law has received ample experimental verification throughout the range over which temperature measurements can be made. As previously mentioned, the first satisfactory radiation pyrometer was that designed by Le Chatelier. The instrument is really a form of photometer, in that it is arranged to match the luminous radiation obtained from an incandescent body against that obtained from a standard lamp. This instrument in the form modified by Féry is still one of the most useful of pyrometers, more particularly as the temperature of very small hot bodies can be measured with it as well as that of large ones. The instrument is shown in diagrammatic representation in Fig. 20. It consists of a telescope DB which carries a small comparison lamp E attached laterally. The image of the flame of this lamp is projected on to a mirror, F, placed at 45 deg. at the principal focus of the telescope, the mirror being silvered only over a narrow vertical slip, A. The telescope is focussed on the object the temperature of which it is desired to measure, the object being viewed on either side of the silvered strip. A colored glass in the eye-piece ensures monochromatic conditions. A pair of absorbing-glass wedges C and C_1 are placed in front of the objective of the telescope, and these wedges are moved laterally by means of a screw until the light from the object under observation is made photometrically equal to that emitted by the standard lamp.[10] A table provided with the instruments converts the readings obtained by the scale into degrees Centigrade. Auxiliary dark glasses enable the instrument to be worked over an extended scale. The cross-section shows the telescope focussed on a filament of a lamp.

The Shore Pyroscope is similar to the Le Chatelier Optical Pyrometer, except that the parts are arranged in a slightly different manner. The intensity of illumination received from the hot body is varied by means of a diaphragm, the temperature being read off directly on a scale controlled by the diaphragm.

The Wanner pyrometer is another successful form of photometric pyrometer and one which is largely employed on the Continent. The comparison light is a small incandescent lamp illuminating a glass matt surface; monochromatic red light is produced by means of a direct-vision spectroscope and screen, cutting out all but a narrow band in the red, and the photometric comparison is made by adjusting to equal brightness both halves of the photometric field by means of a polarizing arrangement.

The Holborn-Kurlbaum pyrometer is also a photometric instrument of rather a different character. If a sufficient current is sent through the filament of an electric lamp, the filament glows red at first, and as the current is increased, the filament, getting hotter, becomes orange, yellow and white successively. If now this filament is interposed between the eye and an incandescent body, the current through the lamp may be adjusted until a portion of the filament is of the same color and brightness as the object. When this occurs, this part of the filament becomes invisible against the bright background, and the current then becomes a measure of the temperature. Fig. 21 shows this pyrometer diagrammatically. A small 4-volt incandescent lamp L, with a horseshoe filament, is mounted in the focal plane of the objective and of the eye-piece of a telescope provided with suitable stops DDD and a focussing screw S. The lamp circuit is provided with a two-cell battery B, a rheostat, and a sensitive ammeter. The telescope is focussed on the incandescent body, thus bringing its image into the plane AC. The current is then adjusted by means of the rheostat until the tip of the lamp filament disappears against the bright background. A previous calibration of the current, in terms of temperature for the particular lamp used, will then give the temperature of the hot body. It is found in practice that different observers do not differ by any appreciable amount in their readings, and at low temperatures the same values are obtained whether a red glass is used in the eye-piece or not.

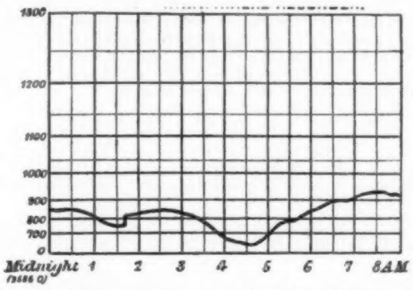


Fig. 24.—Temperature record obtained by means of the Féry radiation pyrometer in conjunction with a thread recorder.

Radiation pyrometers differ from the optical types previously discussed in that they employ all the radiation received from the hot body and not only the luminous rays. The first practical form of pyrometer making use of total radiation was invented by Féry.[11] The instrument is shown in section in Fig. 22 and is mounted on a tripod for use. The radiation from the hot body is focussed by means of the concave mirror on to a sensitive thermo-couple mounted at D; the electro-motive force generated by the couple is indicated on a galvanometer connected to the terminals BB.

In a second and later form of the instrument Féry has replaced the thermo-couple and galvanometer by a bimetallic (nickel-steel and brass) spiral placed in the focus of the mirror. When heated, the spiral uncoils and carries an aluminium pointer over a dial divided in degrees of temperature.

Foster[12] has introduced a modification, Fig. 23, of Féry's pyrometer by putting the thermo-couple D and the aperture E F at the conjugate foci of the mirror C. It has the drawback that a considerable area of hot body is erquired in order that the whole aperture E F may be filled with heat rays. Thwing[13] has also introduced an instrument in which the reflecting mirror is replaced by a bright cone, which by multiple reflection concentrates the radiation at its apex on to one or more thermo-couples.

The author, in conjunction with Professor Féry, has introduced a modification of the radiation pyrometer, in which the mirror is focussed on to the inside end of a long closed tube, Fig. 18, thus rendering the instruments' readings independent of the nature of the furnace or material into which the tube is placed. This pyrometer is particularly suitable for determining the temperature of molten metal in a crucible, the tube being plunged directly into the metal.

Total radiation instruments have the great advantage that they are independent of the color judgment of the observer, and that the temperatures are given directly by a pointer on a dial. In the case of the Féry radiation pyrometers, the particular part of the hot body the temperature of which it is wished to know can be directly focussed on to the sensitive element in the pyrometer. In the case of those in which the sensitive element is a thermo-couple, the instrument can be made recording if used in conjunction with an instrument such as the thread-recorder; the record reproduced in Fig. 24 is a reproduction of such a record.

A great many observers have difficulty in using radiation pyrometers successfully because they have not fully realized the capabilities and limitations of the instruments, and it may be helpful to consider these briefly. The quantity of heat received by a pyrometer from a hot body depends upon:—

1. The temperature, area and emissivity of the hot body.
2. The area and absorbing power of the receiving surface of the pyrometer, and
3. The distance between the hot body and the pyrometer.

It may at once be assumed that the observer cannot readily alter the conditions in 2, as they have been prepared after careful thought by the instrument maker. The question of the emissivity has been discussed previously, but it cannot be too strongly urged that true temperatures will not be given if the hot body is not under black-body conditions, and that the difference between true and black-body temperatures varies with the material, being, for example, much greater in the case of molten copper than in molten iron. Fortunately, in the case of muffles or furnaces the conditions are generally very good, closely approximating to those of the ideal black body.

The questions of the area of the hot body and its distance from the pyrometer are closely linked together. The quantity of heat given off is proportional to the area of the radiating surface and varies inversely as the square of the distance from the body. But the apparent area of the hot body (when looked at by the pyrometer telescope) varies directly as the square of the distance from the body, so that the quantity of heat obtained by the pyrometer is independent of the distance so long as the image of the hot body completely covers the sensitive element of the pyrometer. It is thus of fundamental importance to see that the image of the hot body completely covers the sensitive element; if it is found impossible to get sufficiently near to ensure these conditions, then recourse must be had to an optical pyrometer which depends on color matching only.

The Olfactory Nerve of Insects

A GREAT number of facts of the life of insects can hardly be explained excepting by admitting a particularly powerful olfactory sense in these animals. The examples are numerous; if, in an ant hill, an ant of the same species as those that inhabit it, but belonging to another swarm, tries to penetrate, it will immediately be expelled. Sometimes the hypothesis has been supposed of a sort of language allowing each individual to make itself known, but deafness is general in the class of insects, and ants in particular are absolutely deaf. So then there only remains the odor special to each swarm which appears to constitute a mode of identification. In the same way, when the corpse of a small mammiferous animal is becoming decomposed in a field, a legion of sylphs and necrophors, strangers to the immediate neighborhood, coming sometimes from a distance of several kilometers, arrive to lay their eggs there, guided, it would seem, merely by their sense of smell. It is also their scent which leads the sacred scarabeus to the excrements of herbivorous animals, of which it will make a ball in which to place its progeniture, etc. But is it really scent that guides the insect? Very little is known on the subject; the only precise experiments are due to Fabre, the learned entomologist of Serignan, to whom are due those marvelous studies on the life of insects that he has so well related in his "Entomological Mémoires." The starting point of these experiments was the sexual attraction in butterflies, well known to entomologists, which enables individual insects to meet in spite of the often considerable distance and difficulties of the way. Fabre enclosed females of different species of butterflies in a metallic trellis, and found that numerous males arrived. A remarkable particularity of these experiments was that one of the specimens studied had very rarely been observed in the region. On the contrary, if the females were shut up under an hermetically closed glass globe the attraction ceased, but all objects, branches, stuff, paper, on which they had rested for some time was seen to be possessed of the same attractive properties. Fabre has concluded from these results that a particular odor exists incapable of affecting our sense of smell, but which can be transmitted to a great distance. Although it is bold to generalize, it seems possible to admit that insects are endowed with a wonderfully strong olfacto y sense which no other animal possesses.—*Chemical News.*

[8] "The Measurement of High Temperatures," G. K. Burgess, page 242.

[9] The laws of radiation and the various forms of optical and radiation pyrometers are fully discussed in Dr. Burgess's book. Two other good *résumés* of the subject have also been published: (1) "Optical Pyrometry," C. W. Waidner and G. K. Burgess (*Bulletin No. 2 of the Bureau of Standards*), and (2) "The Black Body and the Measurement of Extreme Temperatures," A. L. Day and C. E. Van Ostrand (*Astrophysical Journal*, vol. xix. 1–40). Reference should also be made to the chapters dealing with radiation in "The Theory of Heat," Second edition, Thomas Preston (Macmillan and Co.).

"Pyrometry," C. R. Darling, chapter iv. Publisher, E. and F. N. Spon & Co., and the excellent small book "Radiation," P. Phillips (T. C. and E. C. Jack, Long Acre, London.)

[10] It can be shown theoretically that the thickness of the wedge is inversely proportional to the absolute temperature, so that the calibration may be effected by finding the thickness of wedge for two temperatures only. See "The Measurement of High Temperatures," *loc. cit.*, page 315.

[11] "The Measurement of High Temperatures and Stefan's Law," C. Féry, *Comptes Rendus de l'Academie des Sciences*, vol. 134, page 977. 1902.

[12] "A New Radiation Pyrometer," C. E. Foster, *Trans. American Electrochemical Soc.*, vol. 17, page 223. 1910.

[13] "Two New Pyrometers and the Application of the Radiation Pyrometer for determining the temperature of molten Iron and Copper," Paper by Dr. C. B. Thwing, Philadelphia, in *Journal of Electro-Chemical and Metallurgical Industry*, vol. iv. February, 1908, page 82



The gases, containing the particles of unconsumed carbon, dust and ash are turned downward at high velocity into a tank of water. The bottom of the smoke passage forms the tank. The gases are turned downward by a damper (the chain suspended plates in the picture at the left), the bottom of which forms one side of a slot-like opening with the side of the tank. The slot is the point of high velocity and on entering the tank the gases are sharply diverted. The opposite face of the damper to that shown in the picture is kept wet and the little waterfall from it, and through which the gases on entering from the slot have to pass is shown at the bottom of the picture. The piping shown is for washing out of the tank the material caught every twenty-four hours. The picture at the center shows the pipe supplying water to the wetted face of the damper and the mechanism for raising and lowering the damper according to the volume of gases handled. The picture on the extreme right shows the centrifugal pumps for circulating the water used in the catcher.

Apparatus for Catching Cinders in Gases*

A Method Applicable to Blast Furnace Gas Cleaning

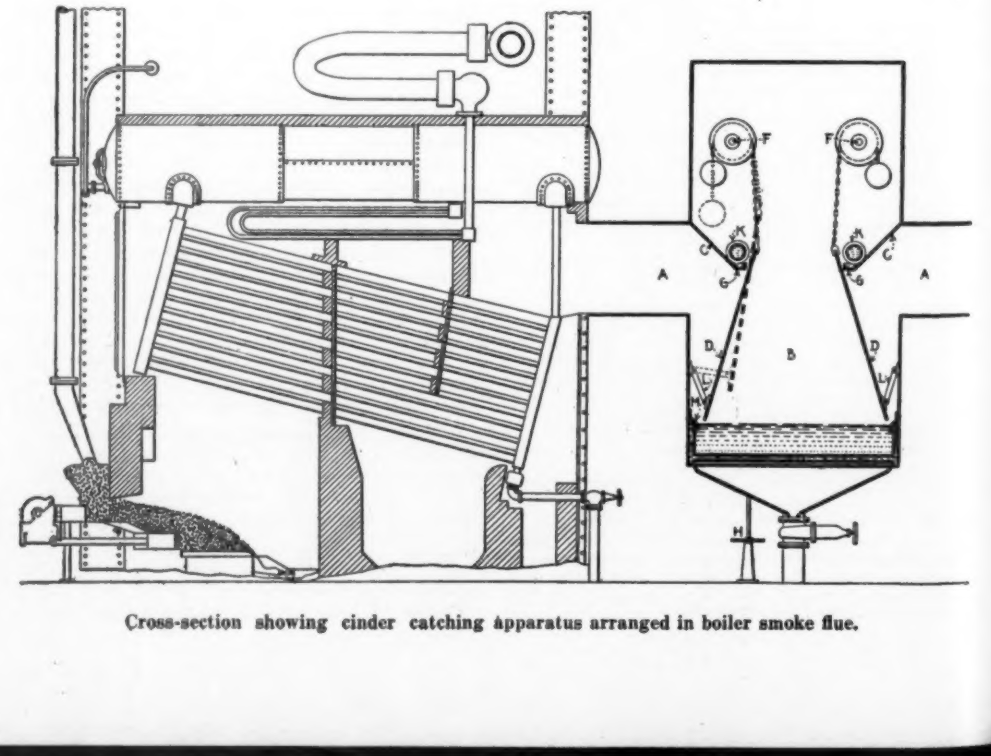
A new apparatus for cleaning the gaseous products of combustion, showing, it is stated, an average efficiency of no less than 95 per cent, has been developed by the New York Edison Company at its Waterside No. 2 station, on the East River, New York city. The apparatus is the result of some years of experiment, and so successful is it with the immense volumes of gases which are treated, many times larger, for example, than the volume handled at a blast furnace plant, that it would seem to have an application of very wide scope. Accordingly, it is expected that it will be employed in the steel industry for the purification of blast furnace gas for use in gas engines and hot stoves, and in cement plants. The facts concerning the system and the photographs from which the accompanying illustrations were made were obtained from C. B. Grady, who had much to do with the carrying out of the experimental work.

The accompanying drawing is a cross-section of one of the boiler settings, showing the apparatus arranged in the main smoke flue. The steam boilers in the Waterside station are placed in rows, back to back, and the drawing shows how the gases of combustion approach the apparatus from opposite directions. Some idea of the size of the installation may be gained when it is realized that the power station contains 96 steam boilers of 650 horse-power rating, which boilers, however, are operated much above the normal rated capacity. The boilers are arranged on two floors, with 48 on each floor. The movable damper *D* in the drawing is about 5 feet high and 50 feet long, running the entire length of the flue. The water tank at the bottom of the flue is 8½ feet wide by 50 feet long, and about 18 inches of water is maintained in the tank. Water is taken from the tank and pumped into the water pipe *K* by means of a small low-head centrifugal pump. The water flows out of the pipe *K* through a number of 1-inch holes, spaced about 4 inches center to center, into the gutter, *G*, then flows over the edge of the gutter *G* down the inside face of the damper *D* into the tank. About 75 gallons of water per minute per boiler are thus circulated, and about 8 gallons per minute per boiler are added to make up for the evaporation and for the water spray which is carried away by the gases. Salt water is used at the Waterside stations, the water being taken from the fire service.

The gases originally left each boiler at the rear through a horizontal intake *A* and traveled along a horizontal rectangular flue *B* to the stacks. There are four stacks all told, each 264 feet in hight above the second-floor boiler grates. The new arrangement with the cinder catchers is as follows: The gases leave the boiler through the same horizontal intake *A* and are deflected downward by a baffle plate *C* and then pass down through a wedge-shaped duct, one side of which is formed by the movable damper *D* and the other side by one of the sides of the flue. The above-mentioned duct is of uniformly decreasing cross-section and is open at the lower end, so that the direction of flow of the gases as they leave the duct is substantially vertical. In passing through the cinder catcher the gases are fanned out, so that they leave the bottom of the catcher through a narrow, long slot. The water level in the lower portion of the flue is kept constant and at a comparatively short distance from the bottom of the damper *D*. The water flowing into the gutter *G* and running over the edge of the gutter forms a sheet of water on the damper *D* which makes a little waterfall from the bottom of the damper *D* to the water in the bottom of the flue.

The cinders are caught either by coming in contact with the sheet of water on the damper *D* and thus being carried into the water below or are projected into the water in the bottom of the flue by the comparatively high velocity that they have attained. This velocity is attained partly by the increase in the velocity of the gas current in which the cinders are suspended and partly by gravity. This is an important feature, for the inertia of the solid particles varies in proportion to the square of the velocity and the resistance of the projected particles to any force tending to change their direction of travel varies as the inertia. It is estimated that the cinders are projected toward the surface of the water with a velocity of about 50 feet per second.

Two positions of the damper *D* are shown. The position showing the damper *D* in full lines is used when the boilers are operating at light loads and the position showing the damper in dotted lines is used when the boilers are operating at a maximum load. The dampers are raised and lowered by turning the shaft *F* which is operated from the boiler room floor by means of a hand wheel *H*. The lower portion of the movable damper *D* is connected to the side of the flue by means of a link *L* so that the bottom of the damper *D* will move upwardly and outwardly when the top of the damper is raised, and maintain the distance from the side of the flue to the bottom of the damper and the distance from the surface of the water to the bottom of the damper approximately equal.



Cross-section showing cinder catching apparatus arranged in boiler smoke flue.

* Reproduced from the *Iron Age*.

The wet method of cleaning was not considered at the outset, but instead a number of experiments were made to avoid the use of water, which, it was thought, would be detrimental from a number of standpoints, and it should be added that the cinders, so called, include not only the dust and ash carried away from the fuel bed, but small particles of unconsumed carbon, all of which are drawn up the stack and blown into the atmosphere.

The first experimental wet-cleaning apparatus consisted of a curved baffle plate placed just beyond the boiler outfit, so as to deflect the gases in a downward direction and a water tank below to catch the cinders. This simple scheme caught quite a percentage of the solid matter carried by the gases, and the next step was to increase the distance traveled by the gases in a downward direction and also materially increase the velocity, so that the solid particles would be driven toward the water with a higher velocity and thus trap a larger percentage of cinders. The first experimental outfit of this type gave remarkably good results. The gases were conducted downwardly through a four-sided, wedge-shaped duct tapering toward the outlet, three sides of the duct being vertical and the other inclined, the water level in the tank being maintained about 12 inches from the bottom of the duct. At the same time another scheme for wet cleaning was being tried out. An inclined baffle was placed in another flue and a sheet of water was maintained, flowing over the upper face of the baffle, so that the gases would tend to drive the solid particles against this sheet of water. The next move was to combine this idea with the former and let a sheet of water flow down along the inclined side of the duct into the watertank below, so that the gases in entering and going through the duct would drive a portion of the cinders into this sheet of water. Tests on this experimental device led to the apparatus now in use.

One of the first ideas considered in the study of the dust-elimination problems was to enlarge the smoke flues, so as to reduce the velocity of the gases, allowing the solid particles to settle to the bottom of the chamber. The velocity was reduced to less than one half of the original, and about 40 per cent of the cinders were caught. Later baffles were introduced, perpendicular to the direction of flow of the gases, and only a slightly increased percentage of cinders was caught, and in addition there was interference with the draft. It was then thought that perhaps economizers, in which the tubes are staggered, would result in intercepting cinders, and 24 of the boilers were equipped with economizers, but the installation did not remove a large quantity of the suspended solids, and as there was also interference of draft in this case the economizers were removed. Another method tried was that of passing the gases through filtering material, a wire screen being used at the bottom of one of the stacks. The screen was given a reciprocating motion, and a part of it remained inside of the uptake while the other part was outside, and the outside part was cleaned by means of brushes. A number of different sizes of screens was tried, but when a screen was fine enough to catch 50 per cent of the cinders it interfered too much with the draft and the cleaning of the screen was difficult. The idea of employing centrifugal force for removing cinders was tried, the scheme being to impart a whirling motion to the gases, throwing the cinders out into pockets. Tests on experimental cleaners of this type were not satisfactory, nor was a combination of the enlarged flue and the centrifugal filter altogether satisfactory. Apparatus was also installed to precipitate the particles according to the Cottrell electrification method, but there was difficulty in connection with the insulation under the high potentials employed.

The adopted form of cinder catcher does not materially reduce the boiler capacity. With a draft at the stack base of from 0.9 to 1.2 inches of water a load of 1,500 horse-power can be carried on each 650 horse-power boiler with only a slight decrease in the efficiency of the cinder catcher. The position of the baffle is always maintained at such a point that the gas velocity leaving the baffle is the highest possible with the stack draft obtainable; thus, under normal draft conditions with boilers operating at 110 per cent and 150 per cent. of rating the baffle opening would be from 3 to 6 inches, while for 225 per cent of the boiler rating the opening would be increased to 14 inches.

The gases coming from the boilers at the Waterside stations contain about 0.06 per cent of sulphur dioxide gases, and a certain amount of sulphurous acid is formed by the flue gases coming in contact with water. The gases as they leave the cinder catcher carry with them a certain amount of entrained water which is slightly acid, and the water in the tank after a run of 24 hours is found to contain 0.025 per cent of sulphurous and sulphuric acid, a small percentage of the sulphurous acid probably having been changed to sulphuric acid by the absorption of another atom of oxygen. The presence of the sulphurous and sulphuric acids and also of a small amount of hydrochloric acid, formed by the combination of the sulphuric acid and the salt in the water used, has given considerable trouble, due to the fact that ordinary iron and other metals which have been used for the damper *D* have been rapidly eaten away.

The baffle plate *C* and the movable damper *D* in the first experimental cinder catcher were made of sheet iron. After a two weeks' run this material showed signs of rapid deterioration. A number of other materials have been tried and copper is now being used for both baffle plate and damper. The dampers are of No. 8 gage copper, flanged and bolted together with ⅜-inch copper bolts, the ends being reinforced with a 2½-inch copper bar. The copper is withstanding the acid action better than anything else which has been tried. The inside face of the damper *D* on which the water runs shows practically no deterioration after two months' use, but the outside face of the damper has been slightly attacked. Experiments are being made on a number of acid-proof and heat-resisting coatings to protect the outside face.

The flues at the Waterside stations are composed of ⅜-inch steel plate reinforced with angle irons and are painted inside and out with two coats of red lead and linseed oil paint. A lead lining has been placed at the bottom of the flue forming the water tank. The lead is about ⅛ inch thick and a concrete mattress about 1½ inches thick is placed between the steel plate of the flue and the lead lining. The upper portion of this lead lining is protected from the heat by a copper flashing *M*. No other protection has been given to the inside of the flue. The first cinder catcher was placed in operation not many months ago and the lead lining and all inside surfaces of the flue proper have shown practically no signs of deterioration.

On the basis of a number of tests an average efficiency of 95 per cent in cleaning the cinders is claimed. This, it is figured, is equivalent to cleaning the gases down to 0.02 grain per cubic foot, a figure comparing favorably with results obtained with scrubbers and washers used in blast furnace gas-cleaning plants. From the nature of the apparatus and the results obtained it is felt that it is applicable for use in steel and cement mills, and that in some form it may be applied to steam locomotives where fire from sparks has been a loss to properties bordering on railroads.

With regard to the illustrations, it may be pointed out that one shows a general view of the cinder catcher, in which water may be seen flowing from the lower portion of the movable damper into the water tank below, the gases as they leave the cinder catcher passing through this waterfall. The pipes in the foreground a e used for washing out the cinders in the water tank, which is done every 24 hours. Another illustration gives a view of the upper portion of the cinder catcher and the mechanism for raising and lowering the movable damper. Water is shown flowing out of the cast-iron pipe, located just above the top of the movable damper into the copper gutter, which is behind the upper portion of the damper. The third halftone illustration shows the centrifugal pump used for circulating the water, this particular installation serving six of the 650 horse-power boilers.

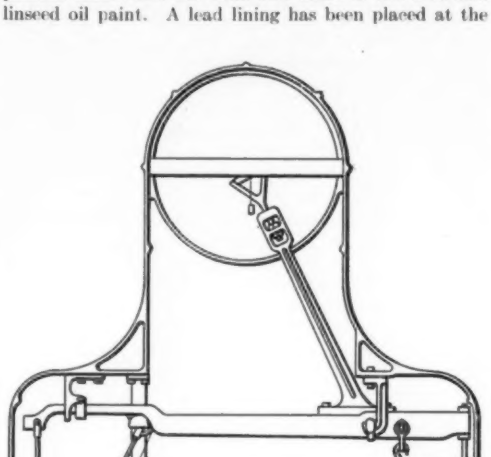
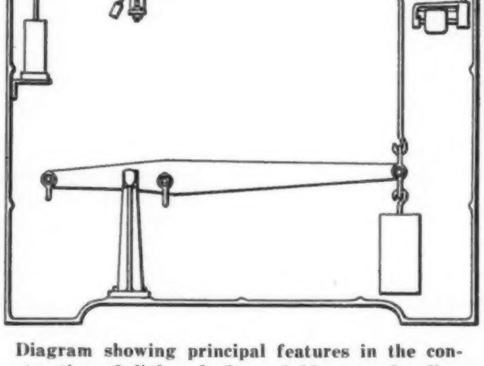


Diagram showing principal features in the construction of dial scale for weighing merchandise.



View showing external appearance of dial scale, and steel yard exposed.

Dial Scales

By F. E. Kaeppel

Several meritorious devices have recently been placed upon the market which simplify the present methods of weighing with beams and weights. A dial is attached to the scale levers which operate the indicator by means of a rack and pinion, this indicator responds instantaneously when the scale is loaded and the operator obtains the weight by simply reading the dial, no manipulation being necessary. The entire mechanism is springless, the results being obtained by means of levers attached to pivots and bearings.

Great economy is derived from this method. First of all in the matter of time. Comparing this instantaneous method with the beam method, namely, the manipulation of a sliding poise back and forth, the adjustment of weights until proper equilibrium is obtained is certainly in favor of the former. Authorities on weighing claim a saving of 40 per cent, that is 40 per cent more merchandise can be weighed by this method than by the other, besides this there is the feature of accuracy; with this new method error is almost entirely eliminated, in fact, the only mistake which might occur would be the wrong tabulation of figures. These devices have undergone practical tests of long duration and have demonstrated efficiency satisfactory to be adopted by most of the leading railroads and industrial concerns throughout the country.

The face of the dial is usually graduated to not more than 2,000 pounds, the average load, as trucked over scales, is usually much less, occasionally there are weights as high as 10,000 pounds brought over these scales. It is, however, impractical to graduate the dial to the full capacity, as this would make the area so large that it would almost be prohibitive. In order, however, to weigh to the maximum capacity, a beam is furnished over the 2,000 pounds, this is used as an auxiliary and works in unison with the indicator.

There are several makes on the market and while they differ somewhat in their mechanical construction they are nevertheless in principle very similar. We show here a photograph of one of the leading makes. As seen from this the beam outfit of the scale is entirely eliminated, the machine being attached directly to the nose irons of the main levers by means of a steelyard rod. The mechanism is arranged in a self contained case, a shelf or fifth lever being provided of any multiple to suit various modifications of scales. The load from the scale levers is transferred through the shelf lever and thence to the beam, to this beam is attached the indicator. Pin point pivots are provided for the indicator fitted with agate at each end. The indicator responds promptly and there is absolutely no vibration, the stop being instantaneous and precise. These devices can be adjusted to old scales as well as new. Scale manufacturers are of the opinion that in time this method will be used on all modifications of scales and that the beam will be eliminated.

The Origin and Significance of Starch*

Its Importance in Plant and Animal Economy

By Ernest D. Clark

INTRODUCTION.

The green leaves of plants possess the most efficient means of transforming the radiant energy of sun-light into the potential energy of carbohydrates like starch, cellulose and sugars. This process which is of fundamental importance to both plants and animals, is carried on by the chloroplasts or chlorophyll-bearing granules of the plant cell. Drawing upon the sun as their source of energy plants are the producers of a form of energy stored in carbohydrates while animals dissipate this energy in the functions of their bodies. They are spendthrifts, too, and were it not for the equilibrium maintained between these opposed functions in animals and plants the world would long since have become bankrupt for the energy so necessary for the existence of living organisms and human industries. These chloroplasts of plants provide the means of absorbing and storing for later use the incalculable amounts of radiant energy poured down upon us daily by the sun. The cellulose present to such a great extent in all living vegetation, and also in the carbonized plant remains in coal, represents one type of energy stored in carbohydrates. In starch we have another example except that it does not form such a permanent reserve for it is consumed relatively soon either by the plant producing it or by an animal. It is this *active* rôle of starch in its biological relations that makes it interesting. The origin of starch in the plant has offered an attractive field of study that has been worked very industriously for a long time. The biological significance of starch is something that appeals strongly to the biochemist. The industries in which starch figures are great ones and worthy of the closest study but in this place we are concerned with starch in its early history long before it has entered into the food and industries of the people.

EARLY THEORIES OF STARCH FORMATION.

Before we can obtain any idea of the mechanism of the green leaf in its rôle of starch former we must consider the point of view of the early investigators. First of all, however, it is desirable to define the term *photosynthesis* which is used by many plant physiologists and will often appear in this paper. By photosynthesis we mean the action of the green plant in *using the radiant energy from the sun to effect the union of carbon dioxid and water thus producing gaseous oxygen and sugars* which subsequently may appear as carbohydrates or may be changed into the fats and proteins of the plant. This phenomenon has been and is still sometimes called carbon assimilation. The latter term expresses the idea correctly but does not make enough differentiation between the action of the green plant which *manufactures* its own carbon compounds and that of the lower plants and animals which can only use such compounds in assimilation after they have been elaborated elsewhere. Furthermore, the word photosynthesis clearly expresses the idea that *light* is the fundamental fact in this type of assimilation.

Priestly, to whom the chemists owe so much, found that green plants would grow in confined air rendered irrespirable by the combustion of a candle or exhalations of an animal. He said:

"Accordingly on the 17th of August, 1771, I put a sprig of mint into a quantity of air, in which a wax candle had burned out, and found that, on the 27th of the same month, another candle burned perfectly well in it. This experiment I repeated, without the least variation in the event, not less than eight or ten times in the remainder of the summer."

Later, in 1779, Ingenhouss showed that this purification of bad air by growing plants could take place *only in the light*. Next, Senebier proved in 1782 that the carbon dioxid in water, in the soil humus, etc., was far too slight in amount to supply the needs of the plant and that the *atmospheric* carbon dioxid was the source of carbon dioxid for the plant. Lavoisier overthrew the phlogiston theory in which Priestly and the others believed. His methods of exact quantitative study were followed by Saussure who announced in 1804 that there were definite quantitative relations existing between the intake of carbon dioxid, output of oxygen, etc. This bare outline of the early history of the study of photosynthesis will serve as an introduction to the later work which will now be treated under several heads in order to keep a clear outline before the reader.

THE FORMATION OF STARCH.

Decomposition of Carbon Dioxid.—When an aquatic plant is illuminated the most obvious result of photosynthesis is the appearance of bubbles of gas. Upon chemical examination this gas proves to be nearly pure oxygen. By counting the number of bubbles produced in a given time one may estimate roughly the rate of photosynthetic action. By exact measurement in eudiometer tubes it is found that for every volume of carbon dioxid absorbed an *equal* volume of oxygen is set free. This is an important observation and will be referred to later. Such plants when submerged in dilute solutions of reduced dyes or venous blood cause the color changes characteristic of oxidation. The so-called bacterium method of Englemann offers a most striking means of demonstrating the production of oxygen when green plants are exposed to light. He used an air-tight preparation of a living green alga surrounded by certain bacteria which are strongly attracted by oxygen but are motionless in its absence. Now, when such a preparation is illuminated these bacteria immediately become active and all move to the centers of oxygen production which are *only* those cells in the *light*. In the darkness and the presence of light of wave-lengths too short or too long to be visible the amount of oxygen set free is small and consequently the bacteria are motionless.

The power to decompose carbon dioxid into oxygen and to build up sugars seems to be localized in the chloroplasts or green granules of the cell. For photosynthesis to go on it is necessary that we have the following intact mechanism in the leaf: The living chloroplast, a sufficient supply of carbon dioxid, light of the proper wave-length, the proper temperature and an adequate supply of water. The last is usually ample because the evaporation from the leaves create a constant transpiration current of water from the roots where it is absorbed through the stem to the leaf. The supply of carbon dioxid comes from the atmosphere where it is constantly present to the extent of 3 or 4 parts per 10,000. This seems to be a very small working capital but when we consider the easy access to the interior of the leaf through the multitude of little openings or stomata one realizes that while photosynthesis is taking place the internal leaf structure is a *vacuum* as far as carbon dioxid is concerned, and so the atmospheric store of this gas is ample for the purposes of the plant. However, it should be stated that an increase of carbon dioxid to ten times its ordinary amount seems to be used by the green plant to good advantage. Millions of tons of that gas are poured into the atmosphere by the respiration of all living things, the decomposition of organic matter by micro-organisms, and the combustion of fuel in the furnaces of industries and homes yet the balance is maintained by the green vegetation of the earth which decomposes this carbon dioxid to build up enormous amounts of organic matter, renewing the air at the same time with the life-giving oxygen. The water and air currents flow this way and that, thus helping in mixing and transporting the gases and keeping conditions uniform for plants both on land and in the water. In Carboniferous times green plants were in their glory because the conditions of high temperature, high content of carbon dioxid in the atmosphere and an abundant supply of water allowed them to reach an unequalled period of activity, the story of which can be read to-day in the world's coal mines.

Rôle of Chlorophyll.—Besides the undoubtedly esthetic part played by chlorophyll in clothing the earth's vegetation with its restful green color it also plays a necessary part as the active agent in photosynthesis. In the chloroplasts this green coloring matter exists either in the form of a thin skin over the protoplasm or in granules within it. The chlorophyll may be extracted with alcohol to give a dark green solution having a beautiful red fluorescence in reflected light. Such an alcoholic solution when shaken with benzene yields a yellow alcoholic layer and benzene soluble fraction having a blue-green color. The yellow substance is mostly carotene hydrocarbon crystalizing in orange plates and having the empirical formula C_{40}, H_{56}. The blue-green fraction has a much more complex nature and is a mixture of the so-called "chlorophyll" or cyanophyll with other closely related substances. The photosynthesic activity is associated with the blue-green pigment and consequently much study has been given to it. It may be obtained in a crystalline form but probably in an altered condition. Many formulæ have been given it; some investigators claiming that it contains nitrogen and phosphorus (a lecithin-like substance), and others that it contains a high percentage of magnesium.

The literature of chlorophyll is voluminous and investigators like Willstaetter, Machlewski, Stoklasa and others have all carried on series of researches upon tt. Among the decomposition products of chlorophyll there are found substances nearly identical with those trom haemoglobin, which is as essential for the continuance of the life of higher animals as chlorophyll is or the green plants. Any detailed discussion of the chemistry of chlorophyll would be out of place here but for many it is a fascinating chapter in modern organic chemistry.

Action of Sunlight.—An alcoholic solution of chlorophyll shows a striking absorption band in the red which corresponds to wave-lengths of about 640 to 670 microns. Experiments with spectra thrown on living leaves show that it is in just this region of the spectrum that the greatest formation of starch takes place. So, then, it is the energy absorbed from this region that carries on the photosynthetic transformations. The energy thus absorbed is largely turned into heat which always raises the temperature of the leaf and consequently only a small fraction of the absorbed energy is ever converted into the potential energy of carbohydrates, etc. On a bright summer day when we absorb certain light rays with our skin the energy thus converted soon causes the well-known unpleasant effects, and likewise when this action takes place on a photographic plate the sensitive silver salts are altered in such a manner that a permanent record of any scene may be produced at will. Some think that chlorophyll acts as a sensitizer in photosynthesis just as certain fluorescent substances do in other photochemical reactions. Others look upon the rôle of chlorophyll as being that of aiding in the transformation of radiant into electrical energy which then splits the carbon dioxid and water into the first products of photosynthesis.

The amount of light required for photosynthesis is not great and so upon exposure to weak illumination the process of carbon dioxid decomposition begins at once but may not become evident since the evolution of oxygen does not occur until the amount set free is in *excess* of that required for the processes of respiration. It is likely that in most conditions under which plants exist the limiting factor in photosynthesis is not lack of light but absence of sufficient carbon dioxid, water or favorable temperatures. Certain shade-loving plants thrive in a very dim illumination but in such cases the cells containing the chloroplasts are often arranged like lenses to focus the available light upon the chloroplasts. In ordinary plants the cells have many ingenious ways of focussing light upon the chloroplasts and of securing favorable alignments by means of changes of position of the chloroplasts in relation to the incident light. On a larger scale, we notice, that each leaf tries to secure the most favorable arrangement for itself, an arrangement resulting in the least shading of the leaf by others. This tendency produces "leaf mosaics" of great interest and beauty. Many plants when viewed from above (whence the most light comes) present a nearly unbroken expanse of green leaves thus enabling the plant to make the most of all the light it does receive. The plant even in strong light does not begin to form starch at once when illuminated but only after the lapse of a certain time during which, apparently, the precursor of starch has collected in sufficient quantity to start the mechanism of starch formation. The increase of dry weight of an illuminated leaf does not represent the total amount of products formed but only the quantity *remaining* in the leaf, the rest of the material produced having been translocated in diffusible form to another organ of the plant where it is laid down in the form of the "secondary starch" as in potato tubers.

Nature of Photosynthetic Products.—We have already seen that the volume of carbon dioxid absorbed and oxygen disengaged are nearly equal and, further, that the first distinguishable substance is starch. Now, starch has a very high molecular weight, variously estimated at from 12,000 to 30,000, and it does not seem probable that such a complicated substance should be produced at once from water and carbon dioxid. Baeyer's theory that formaldehyde is first produced and that it soon condenses to form sugars is well known and it probably expresses correctly the nature of photosynthesis. It has been generally accepted that glucose is the *first stable* product from which starch, sugars, fats, and proteins may be constructed according to the needs of the organism. In most plants during the day this glucose is rapidly condensed to starch which fills the cells but as evening and darkness ap-

*Paper read before the Eighth International Congress of Applied Chemistry.

proach photosynthesis is retarded and the starch is converted back to glucose and similar easily diffusible substances which are easily translocated to other parts of the plant. Assuming that glucose is the first stable product we may write the reaction for photosynthesis as follows:

$$6\ CO_2 + 6\ H_2O = C_6H_{12}O_6 + 6\ O_2.$$

This equation, however, does not represent the whole truth but indicates only the general trend of transformation, the important but unknown intermediate products as well as the energy relations being ignored. The heat of combustion of glucose is about 3.75 calories and all of this energy must have come from the sun in the beginning.

It is by no means true that all plants store energy in the form of starch although many of them do so. In certain groups of plants such as the lily, orchid and amaryllis families very little if any starch is formed, while in the legumes and solanaceae large quantities are present. When starch is not produced we find substitutes in the form of cane-sugar in several plants, mannite in the oleaceae, etc. The oils, proteins, glucosides and so on are probably not the direct result of photosynthesis but are produced later by the union of glucose with other substances or by condensation with itself to form more complex carbohydrates. The first substances produced by photosynthesis are extremely active chemically and it may well be that, at this stage and in the presence of nitrates, phosphates, and sulphates the proteins are constructed. In the green leaf many optically active substances are formed, a type of synthesis difficult to perform in the laboratory without the intervention of the experimenter or other living organism able to differentiate between the right and left handed modifications.

In darkness, even in the absence of chlorophyll, the plant cells can store up starch if fed with glucose, sucrose, glycerine and many other similar substances. This shows that the photosynthetic and starch forming processes are distinct. Proteins, fats and many other types of organic materials may all be formed in darkness also. Some observers have reported that in the light the chloroplasts of certain algæ seem to show a shrinking and change of their protein substance into starch. It may be that one step in photosynthesis is the disintegration of the protein of the chloroplasts to split off carbohydrate in this manner.

Artificial Photosynthesis.—The idea that formaldehyde is an intermediate product of photosynthetic activity has led many investigators to see first if it really may be detected in green leaves by chemical means and secondly if it may be made to condense and produce sugars artificially. Several investigators have found that leaves do give a positive test for formaldehyde but whether formaldehyde *itself* were present cannot be said. A more complex aldehyde has recently been isolated by Curtius and Franzen from certain leaves. It possesses the six carbon atom skeleton characteristic of glucose. Attempts to cause starch formation by feeding formaldehyde or its derivatives to plants have been partially successful. It is interesting that in alkaline solutions formaldehyde condenses with itself to give a sugar like glucose. Under certain conditions the silent electrical discharge breaks up carbon dioxid into formaldehyde which, in turn, may then be converted into sugars. In the presence of alkalies Stoklasa found that ultra-violet light changed a mixture of carbon dioxid and nascent hydrogen into sugars. When formaldehyde and oxalic acid were sealed in glass tubes and exposed to sunlight, those tubes only which were thus exposed were shown to contain considerable quantities of sorbose. The action of light and of the traces of alkali in the glass seemed to catalyze this reaction. Electricity and ultra-violet light seem to lower the temperature necessary for these condensations to take place. Experiments of a different type have been carried out in which a thin film of chlorophyll was deposited on water or gelatine and then this artificial leaf was illuminated and a little catalase added to decompose any hydrogen peroxide formed. Under conditions of illumination and presence of carbon dioxid the experimenters reported the formation of small quantities of formaldehyde. All of these recent investigations show that the formaldehyde theory of sugar and starch formation has experimental ground for its existence and, at any rate, it is helpful in visualizing some of the processes of photosynthesis. Such observations also force us to consider that, after all, photosynthesis is not wholly a vital process but that under the proper conditions it may be imitated in the laboratory, though in an inefficient manner.

PHYSICAL NATURE OF STARCH.

Ordinarily we see starch in the form of a white powder which gives a peculiar rustling sound when rubbed between the fingers. Under the microscope the whole appearance changes and the starch grain now takes on a characteristic form depending upon the organ and species of plant from which it came. This form is nearly constant for any given type of starch. The size of the grains varies from the large one of the Canna (visible to the naked eye) to the most minute sort. The form of the larger types like the starch from potatoes may best be described by likening them to oyster shells often with eccentric striations. In the case of corn and rice starch we do not have a simple grain but a compound structure consisting of many small grains having more or less angular faces. In polarized light the familiar black cross appears and this shows that the starch grain has a definitely organized structure of some sort.

The effect of starch on polarized light and its peculiar striated or stratified appearance have led to the publication of many theories to explain its internal structure. The layers may probably be accounted for by assuming that they represent the product of varying periods of activity on the part of the functioning chloroplasts or leucoplasts. When starch is formed in the green leaf it is produced on the chloroplast of its origin while in tubers and other storage parts it is made from glucose and maltose by the activity of the leucoplasts or colorless granules which are seats of this storing action. The layers and striations of the grain are seldom concentric because the centers of starch formation are usually not the geometrical center of these protoplasmic granules. The latter are often far smaller than the starch grain growing upon them. It must be remembered that the formation of starch from the products of photosynthesis by either the chloroplasts or leucoplasts has little to do with the photosynthetic function of the former but is controlled by the amount of glucose and maltose in circulation in the plant. Some authors consider that the different layers are caused by variations in the water content of the starch deposited. It was also thought for a long time that the outer envelope of the starch grain was a cellulose because of the well known insolubility of starch in cold water and the difficulty in digesting raw starch by enzyme action. The true starch or amylose was supposed to be in the interior and to imbibe water through the cellulose envelope; this causing a swelling which ruptured the envelope, yielding the familiar starch paste. Arthur Meyer believed starch was composed of sphaero-crystals consisting, in turn, of radiating needle-like crystals of two sorts, one easily soluble in water and giving a blue color with iodine and the other a substance less soluble in water like the cellulose envelope of the earlier writers. The conception of the starch grain as a sphaero-crystal is interesting and there is some experimental evidence for it. At present it is impossible to state with certainty that starch has one type of structure or the other.

THE CHEMICAL NATURE OF STARCH.

We have just seen that starch is apparently composed of two substances, one of which is water soluble and possesses all the properties commonly associated with starch, while the other is more insoluble and more like cellulose in its behavior. Treatment with boiling water, acids, alkalies and digestive ferments gives first a thick colloidal solution having well marked starch reactions which decrease in intensity and finally give place to simple solutions and more active chemical properties as hydrolysis into dextrins and sugars progresses. Soluble starch is the first hydrolytic product but it is soon changed into the dextrine. The chief characteristic of soluble starch is that it dissolves in warm water to give a clear solution having the usual starch properties unchanged. This form of starch may be made by treatment with very dilute acids, alkalies, or by enzyme action, provided, of course, the reaction is arrested at the proper point. A great many interesting and industrially important starch derivatives are manufactured but they are too numerous to mention here.

The blue coloration with iodine is the commonest means of detecting starch and it is a striking and valuable test. Much study has been given it but we still lack accurate information about it. Some consider starch iodid a chemical compound, others an absorption phenomenon and still others think of it as a solid solution of iodin in the colloidal contents of the starch grain. The blue color is easily destroyed by heat but reappears on cooling and, furthermore, it is very easily changed by numerous chemicals. Not all starches stain a pure blue with iodin; some give purple and some even give red colors. This probably indicates a difference in the complexity of starches from different sources. With iodin a shade of red or brown indicates a departure from natural starch and an approach to the simpler dextrins and, finally, to the simplest and well known sugars. During digestion by diastase the starch grain is corroded and attacked more in certain portions than in others. This fact may indicate a difference in chemical nature between the different layers of the grain as already suggested.

In the classification of the carbohydrates starch is listed as a polysaccharid and it is from this word *poly* that we get the key to the whole matter. We ought to consider starch as being built of many glucose and maltose units connected in such a way that no carbonyl groups are free. This we know because, like saccharose, starch shows none of the reactions characteristic of such a group. The usual formula for starch is $(C_6H_{10}O_5)n$ in which n may be any number from 20 to 200. It is almost impossible to obtain accurate data on the molecular weight of starch but from physico-chemical studies, chemical derivatives and ultra-microscopic observations it seems likely that its molecular weight may be from 10,000 to 30,000, figures probably not often equalled even by the complex proteins. In the plant the processes of building up this complicated molecule and of breaking it down seem to be reversible and are probably under the control of enzymes. Apparently the active mass of the glucose and maltose in the food-conducting system of the plant determines the course of this reversible reaction and determines whether its direction shall be toward the storing of starch or toward its hydrolysis into the more diffusible and immediately available sugars. The complexity of starches from different sources is a variable factor and so by starch we can only mean a general term including those substances having most of the reactions and properties commonly associated with the well known starches of commerce. More exact studies upon the chemistry of starch with the improved methods of the recent advances in chemistry ought to yield the most interesting and valuable results.

SIGNIFICANCE OF STARCH IN THE PLANT.

In the earlier sections it has already become evident that starch acts primarily as an indiffusible but easily convertible form of stored energy. The heat of combustion of starch (4.1 Cal.) is slightly higher than that of glucose but as a form of potential energy it cannot compare with the fats and oils which have an energy value of about 9 Cal. However, in many plants starch is the most abundant form of stored food and is, possibly, more easily converted into its constituents for purposes of translocation than are the fats. The proteins are more likely to appear as integral parts of the living protoplasm than to act as stores. Most of the starches with which we are familiar are nearly always prepared from some storage organ of the plant and have larger and better characterized grains than the primary starches in the leaf. The leucoplasts of the fruit pulp, tubers, etc., of the plant are the active agents in reforming starch from the translocation stream of sugars. There is a form of starch storage in which the leucoplasts do not seem to play any part. The type is represented by the somewhat temporary starch reservoirs found in pollen grains, the sheath of growing tissue, and so on. Under such conditions the starch exists in a very finely divided state and appears to be a store of a transient nature. In either form of storage the enzyme diastase seems to cause the transformation of starch into its sugar constituents and also the reverse change when circumstances demand it. The so-called translocation diastase of the green leaf causes the change there while the secretion diastase of germinating seeds and tubers carries on a similar action in those places. The two sorts of diastase do not corrode the starch grains in the same manner nor are their other properties exactly the same. Although starch is laid up in enormous quantities in the tubers, seeds, stems and pulp of fruits, it is far from being the only polysaccharid thus stored. Glycogen has the same function in the fungi and so has inulin among plants of the Compositaceae and Liliaceae; sucrose acts likewise in sugar-cane and beets, while glucose is found in the leaves and bulb of the onion. However, starch and cellulose are the two great stores of energy in the form of carbon compounds that are produced so abundantly by nature each season.

SIGNIFICANCE OF STARCH TO MAN AND ANIMAL.

In the early history of the race our ancestors probably noticed that certain animals and birds sought much of their food in the seeds of grasses while at the same time the smaller animals dug into the earth for roots and tubers. Thus, man early learned to make the starchy foods one of the main articles of his daily fare and it is true to-day that among all peoples in all climates bread from cereals or some starchy substitute is the "staff of life." Among many animals the foods of this type are the staple ration and it is only the carnivora that scorn such a diet. Upon digestion the starches are split into the sugars which are then burned in the organism to yield their energy for the maintenance of the physical activities and physiological functions of the animals. Unlike the proteins, the carbohydrates and fats are used by animals to produce heat and energy and not so much to become living protoplasm as is the case with nucleo-proteins and albumins for example. Since but little new protein is needed for the upkeep and growth of the mature plant or animal we see that the constant demands for energy supplies must be met by the sugars and fats consumed. The abundance of starchy foods eaten by men and animals is adapted to meet this necessity of energy producing material in large quantities.

The greatest source of starchy food is, of course, the

seeds of the various cereals which we group together as grain. The amount of such material produced from the soil in a year is almost beyond calculation. The production of this golden flood of grain is the earth's oldest and greatest industry. Besides the starch given us in the cereals we must not forget the potato which is another staple article of diet in the whole civilized world. In different countries various starchy foods are popular such as sweet potatoes, arrow-root preparations, tapioca, sago, chestnuts, bananas, etc. From the time that man first noticed that grains were good to eat he has taken plants of this type under his special protection and given them careful cultivation. The result has been an improvement in the races of grains as judged by their yield and adaptability to varying conditions of climate. To produce these harvests the soil supplies the water and mineral nutriments while the carbon dioxid and sunlight lend their aid through no effort of man. His duty, then, is to see that the soil is kept in its most productive condition and by so doing he will have an ample supply of grain for the needs of the future.

THE INDUSTRIAL IMPORTANCE OF STARCH.

The observation of primitive man that the seeds of certain plants made an acceptable food was the beginning of agriculture. Another observation made some time later was that when starchy materials were allowed to stand they underwent a peculiar transformation. The result of this change was a so-called "spirit" which was soon found to possess magic properties in making "glad the heart of man." This, then, was the origin of another vast industry whose object is the production of alcoholic materials through the fermentation of grains by enzymes and micro-organisms. Alcoholic beverages of one sort or another are known everywhere and their production goes hand in hand with the practice of agriculture. The amount of grain used by the brewing and liquor distilling industries comes to an enormous figure and is second only to that consumed as bread and various bakery products. The flour milling industries prepare starchy food for the millions, the example of the former in centralization is being followed more and more by the bakeries, especially in the larger cities. The preparation of bread in the home is becoming less common every year and most of this work is done in large bakeries where more or less scientific methods are beginning to prevail. Various forms of natural and prepared starch are employed in large quantities in the form of specially treated foods, laundry starch, sizings, adhesive pastes and so on in great variety. Very valuable products are manufactured by heating or treating raw starch in such a way that dextrins and gums are formed. These are used as adhesives and for other purposes. The action of dilute acid upon starch yields glucose and it is upon this reaction that another great industry has been founded. Glucose has a multitude of industrial applications and it also figures in our food, sometimes under another name but tasting just as sweet. Starch and its products are valuable in many other ways than merely those already mentioned but it would be presumptuous to point them out to this Section of our Congress.

In this paper the writer has not striven to give detailed discussions of any sort for these may be found in books on plant and animal physiology but has endeavored to present many old and a few new ideas in the way that they appear to one interested in the biochemical problems of plants and animals. For those desiring a closer insight into the phenomena of starch formation a short bibliography is appended. In these works full references to the original papers in this field may be obtained.

Pfeffer (translated by Ewart), Physiology of Plants, Vol. I 1900.
Czapek, Biochemie der Pflanzen, Vol. I, 1905.
Palladin, Pflanzenphysiologie, 1911.
Euler, Pflanzenchemie, 1908.
Chodat, Principes de Botanique, 2d ed., 1911.
André, Chimie Végétale, 1909.
Abderhalden (translated by Hall and Defren), Text-book of Physiological Chemistry, 1908.

A Simple Method of Determining the Time*

By Prof. William H. Pickering

When it is only required to know the time within a second or two the following method of obtaining it, without instrumental aid, will be found a very satisfactory one. For certain classes of astronomical work, notably photography, and for many kinds of visual observations, particularly on the planets and brighter stars, this accuracy is all that is needed. When no other work is done at a station, so that the time observations are merely a means to an end, and not the end itself, or in the case of any amateur astronomer who is located far from a telegraph station, and wishes simply to know approximately what time it is, the following method of observation is recommended.

The object in my own case was to waste no time at night on time observations, which might better be applied to work that was worth while. If daylight observations were to be employed, the object must necessarily be the sun.

It was suggested to me by Prof. W. P. Gerrish that by using proper precautions, the time of transit of the shadow of a rod across a line ruled on a screen could be determined within a few seconds. This was found to be the case, and the question was then simply to find the best method of constructing a sun-dial.

A half-inch steel bar, eighteen inches in length, was supported horizontally upon Y's, which were capable of adjustment upon a cast iron base. This was set on the top of a concrete column six feet in height having a cement surface surrounding it. One end of the bar projected about six inches beyond the column. This could all, of course, be much simplified by the amateur who would be satisfied with somewhat less accuracy. By means of two plumb lines sighted on Polaris at upper culmination, it was possible to lay off a meridian with sufficient accuracy, and to mark it by means of screws driven into the flat cement surface at the base of the column. A pencil line was ruled between the slots of the screws. The amateur need only choose a time for sighting on Polaris when δ Cassiopeiae or ζ Ursae Majoris appears directly above or below it. Then by sighting from behind one plumb line upon the other the required meridian will be obtained.

A simple transit of the shadow cast by this rod across the meridian line gives the time of Apparent Noon, but better results are obtained by taking a piece of red paper pasted on a card or envelop, and dividing off its two longer sides into intervals of a quarter of an inch. The middle division is continued straight across the card. The divisions are numbered successively, and the middle division may then be placed so many quarters of an inch on either side of the meridian mark. By sliding the card along, we may in this manner obtain several transits of the shadow across this middle division, instead of only one, as if we used the meridian line directly. By taking five transits symmetrically distributed with regard to the meridian mark, it is found that the average deviation of a single transit is usually in the neighborhood of two seconds. The probable error of the mean would, therefore, be about one second, which is quite as accurate a result as could be obtained with a sextant, and entirely avoids the lengthy and troublesome computation necessary with that instrument. The red paper was selected as being less trying to the eyes than white, but shaded spectacles are also employed for further protection.

In the *Observer's Handbook*, pp. 6 and 7, will be found a column headed "Equation of Time," by which we may convert our Apparent Time directly to Mean Time. A further constant correction must be made for the longitude of the station, to convert to Standard Time, and that is the only computation needed to obtain our results.

While a horizontal bar has been employed in our latitude, + 18 degrees, it is probable that beyond + 45 degrees a vertical rod at a less elevation would give better results, at least, in the winter time. Another method would be to employ two walls lying east and west and situated about six feet apart. The sun shining through a small hole in the southern wall would cast its image on the northern one, and a vertical line ruled on this in the proper place as determined by Polaris would serve to mark the meridian passing through the hole. In the summer time the image would lie on the ground between the two walls. A modification of this plan has been used by Mr. Maxwell Hall, of Jamaica. It has the advantage over the shadow method, that the latter gives trouble when there are thin clouds passing over the face of the sun, the shadow shifting so that it is impossible to obtain a satisfactory result.

By any of these methods the systematic errors are the ones chiefly to be feared. In many places the chief of these would lie in the uncertainty as to the longitude of the station, and this error would affect the most refined instrumental observations equally with those above described. An error of one mile in the assumed longitude would introduce an error of about four seconds in our result, and the farther north we went the greater would this error become.

* Reproduced from the *Journal* of the Royal Astronomical Society of Canada.

Electromagnetic Waves

The laws governing the propagation of radio-telegraphic signals in the atmosphere during the day and during the night are still but imperfectly known, and the development of aeronautics has enabled us to gather some interesting information on this subject. The signals grow weaker as the distance increases, but one of the points to be examined is to know how the height above the ground influences this problem; in other words, are the signals affected by a weaker density, a lower temperature, and by the intense ionization of the high regions of the atmosphere. M. G. Lutz has given several results obtained in utilizing a balloon of 1600 cubic meters, with a circumference of 45 meters. The antenna was formed by a metallic wire of 100 meters long hanging under the basket. During the experiments made in the night, the balloon covered a distance of 120 kilometers at an average altitude of 1,277 meters. It was found that the intensity of the signals received decreased when the distance increased, but that this weakening is not proportional to the square of the distance; it varies as the power 1.96 of the distance and when far from the starting station, as the power 0.88. At an equal distance it is remarked also that the signal is so much the weaker as the balloon is higher. To be more precise on this point, a second ascension was made, the balloon then rising to a height of 6,500 meters. At this height, the intensity of the signals equalled what they would have had on the earth at the same distance from the station. These results are worth being confirmed and completed, for the question is still but very incompletely known, and up till now the experiments have been insufficient.—*Chemical News.*

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